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"ELECTRICITY IN WARFARE."

BY LIEUTENANT B. A. FISKE, U. S. NAVY.

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[*Concluded from Volume CXXI, page 69.*]

In endeavoring to use the telegraph and telephone for strictly naval purposes between ships, a number of obstacles have been met which have not yet been overcome, though many ingenious devices have been attempted. It might seem at first sight as if, in the case of ships at anchor, telegraphic and telephonic communication among the ships, and between the ships and shore, would be an easy thing to establish. It is easy, and it has been established in the case of ships moored so that they cannot swing; but when a ship swings by a long chain, most of which is imbedded in the mud, it becomes very difficult to devise an automatic means to keep the wire from being fouled and broken. In England, in the case of a lightship, the difficulty has been surmounted, or rather avoided, by making the cable, by which the ship rides, hollow, and running an insulated wire along the long tube thus formed inside.

This plan has been found thus far to work very well, even in the worst sort of weather.

But the problem is much simplified when temporary communication only is desired between ships at anchor, between a ship and the shore, or between a ship and a boat which has been sent off on some special service, such as reconnoitring, sounding, etc. In this case, portable telephones are used in which the wire is so placed on a reel in circuit with the telephone, that communication is preserved, even while the wire is running off the reel.

The telephone has been used to some extent on shipboard for communicating between different parts of the same ship, giving orders to the magazines, battery, etc. The vibration of a ship is seldom so excessive as to impair the working of the microphone transmitter; and in cases where it is excessive, the original magneto transmitter has been found to work perfectly, getting rid entirely of trouble, due to vibration, and at a cost only of a little of the loudness of tone as heard in the receiver.

The telegraph and telephone are both coming largely into use in artillery experiments and drills, as in tracking a vessel as she comes up a channel, so that her exact position at each instant is known, for determining the spot of fall of a projectile, etc. In these cases two observers, at the ends of a base line electrically connected, know at each instant the bearing of the vessel, or the projectile, from both ends of the base line, and the intersection of these lines of bearing is, of course, the position of the vessel or the projectile at that instant. In the case of a vessel, this gives the range for the guns, and in the case of a projectile, it shows how much the projectile missed the target. In getting the time of flight of projectiles also, electricity is of value, since it enables the observers to get the exact time of start, a thing impossible to get with stop-watches, but by making the projectile break a wire in circuit with a chronograph, the precise instant of start at least to a thousandth of a second is automatically registered.

An application of electricity, somewhat analogous to this, has been in use for years in what are broadly called velocimeters; that is, instruments for ascertaining the velocity of projectiles. There are scores of patterns, but in all, wires are cut by the projectile at different points of its flight, and the breaking of each wire causes the breaking of the electric current going through it; and this

causes the appearance of marks on a surface moving along at a known speed.

Now, knowing the rate at which this surface moves, and observing the distance on the surface between the marks caused by the breaking of the first wire, and the marks caused by the breaking of the second wire, we can compute the interval of time, which elapsed between breaking of the two wires; and now—knowing this interval of time, and knowing also the distance between the two wires, we can calculate at once the velocity of the projectile in going from one wire to the other.

Within the past few years, electricity has come to be employed to a great and increasing extent in firing great guns both in ships and in forts.

In the case of ships, the advantage of electrical firing lies in the fact that a gun can be fired more quickly by electricity than by other means. The ordinary means of firing are, as is well known, percussion and friction, and in each of these systems the moving parts have to be of such strength that considerable force must be exerted by the arm, in order to operate them; moreover, for prudential reasons, the line leading to them from the hand must be kept very slack, lest a lurch of the ship should cause such a movement of the man's body as to bring a strain on the line sufficient to cause the accidental firing of the gun. Therefore, when the gun captain finds the sights on the gun bear on the target, he must then move his arm through a considerable distance and exert considerable force before the gun will be fired. It may seem as if the time were insignificant, but when it is considered how rapidly a ship rolls, and how swiftly a modern ship moves, and when it is remembered how small an error in the elevation of a gun suffices to make a projectile fall short of, or go over, a ship which subtends a very small angle in a vertical plane, it will be seen that a fire which comes instantaneously with the coincidence of sights and target, is better than one which does not. Now, in firing by electricity the gun captain holds a sort of push-button in his hand, which he simply presses, when the sights bear on the target; and practical experiments abroad have shown that greater accuracy is attainable by this method than is attainable by the old methods. But not only are modern vessels of war fitted with means for electrically firing individual guns; they are also fitted with means for

firing any desired number together, the whole broadside even; for the effect upon an enemy of a blow from a whole broadside at once, is very much greater than the effect of the same number of guns fired at different times.

The simplest way of doing this, is to lead the electrical wires from all the guns to an armored fighting tower, where a cool officer under the personal direction of the commander, with an electrical key-board and a good system of sights, can deliver the whole fire of the broadside at once upon an enemy.

This officer being clear of the smoke and away from the excitement and bustle of the battery and with a view of the whole horizon, can clearly handle a battery with its maximum effectiveness; and, moreover, as soon as the guns have been laid at the range and in the direction at which it is intended to fire them, the men can lie down and be protected in a measure from the murderous fire of machine guns. Suppose that two modern ships are about to engage in a naval duel on the high seas, and that they are advancing towards each other at a speed of fourteen knots an hour each, so that they are coming together at a rate of about forty-six feet per second. The ships will of course begin to play on each other with their machine guns as soon as they get within range, so that as soon as the great guns are ready, the men had best be made to lie down on the deck in rear of them.

Now, the battery of each ship will probably be composed of guns firing projectiles of from 100 to 1,000 pounds, and each commander knowing how much damage can be done by one well-delivered shot, knowing how long it takes to reload a modern gun, and appreciating the great speed at which the ships are approaching, will probably reserve his fire until sure that he has a good chance of making every shot tell. He will hardly fire at 2,000 yards range, knowing that his chance of hitting the rapidly moving target is small, and knowing that it will be only about one minute before the enemy will be at 1,000 yards range. Now, at 1,000 yards range, the machine guns of both ships will be working vigorously, and each ship will have an excellent target, but a target improving so rapidly that a commander will not wish to throw away all the shot of his great guns until a closer range is reached. One gun, for instance, might be fired now, having been previously, of course, laid for this range; but probably it would be

best to reserve nearly the whole broadside to be delivered simultaneously as the ships rush by each other at pretty close range. With the heavy guns and carriages of the present day, it would be impracticable to keep a gun pointing at a ship under these circumstances, since both range and bearing are changing so rapidly; therefore, the guns must be pointed in certain directions, and laid for certain ranges, and fired when the enemy reaches the spots thus defined.

In the case of a fort, the value of firing by electricity is evident, since it can be employed in connection with the instruments used for determining at each instant the position of an approaching vessel or army. Different guns being laid at different ranges, and in different directions, an officer in the operating rooms can keep track of the exact position of the enemy, and when the enemy reaches one of the predetermined points, all he has to do is to touch an electric key and fire the gun, or guns, controlled by that key, knowing that those guns are not only pointed in the proper direction, but also are elevated for the correct range. It would seem difficult to improve upon the accuracy attainable by this method.

Whitehead torpedoes are now so arranged that they can be ejected by pressing an electric button; and the firing key-board in the fighting tower of a ship indicates at any instant what guns and torpedoes are ready for firing. The fighting tower should also be fitted with engine and steering telegraphs, and indicators for showing whether the commander's orders to the engine and steering apparatus have been understood and executed, so that the commander can tell at a glance the exact state of affairs at battery, engine and steering apparatus, and can have all the separate departments of his ship under his personal control.

Within the past three years the superiority of the incandescent electric light over all other forms for ship use has become more and more evident; and now nearly all first-class merchant steamships launched and all men-of-war are fitted with electric lights. In men-of-war, this light has even more advantages than in merchant ships, by reason of its safety in illuminating magazines, shell-rooms, torpedo store-rooms, etc., and the ease and speed with which it can be used in signaling at night.

For some time the electric light was declared unsuitable for naval use, the reason being urged that if the wire carrying the

current should be shot away in action, the whole ship would be plunged into darkness, and that the same thing would happen if any accident should befall the dynamo generating the current. The answer to this very sensible criticism is that, (1.) different circuits must be arranged for different parts of the ship, so that an accident in any part of the ship will affect that part only; (2.) that the wires carrying the current must be arranged in duplicate, so that even in case one wire is shot away the light will burn as brightly as ever, since the other wire remains, and is of sufficient size to carry all the current; (3.) it is very easy to repair a break in a copper wire, even if it be shot away, the only thing necessary being to bridge over the break by a wire a few inches long whose ends can be clamped, spliced or even twisted on to the broken conductor on each side of the break. As to the danger to be feared from accident to the dynamo and engine, this can be guarded against in two ways: (I.) By placing the dynamos and engines in a place as well protected as that occupied by the main boilers and engines of the ship, preferably near the engines, below the water-line and under a protective deck, and this place should be provided in laying down the original plans of the ship. (II.) By not placing dependence on one dynamo and engine alone, but by dividing the total work among three or four, so that in case of accident to one, the ship will have the benefit of all the others. To this end all the dynamos should of course be of the same electro-motive force, and feed into the same mains from which all lamps draw their supply, and which are fed by feeders from the dynamos at different points, so that accident to the mains in one part of the ship will affect that part of the ship only. But it is the arc light, used as what is called a search-light that is most valuable in warfare; a search-light being simply a very powerful arc light so arranged with a catadioptric mirror, that it throws out a very concentrated beam of light, and so mounted that this light can be cast in any desired direction, and made to illuminate any locality which it is desired to inspect. I believe the first use made of search-lights was in the siege of Paris in the Franco-Prussian War, when the French employed them to discover the operations of the besieging army at night. Their value from a military point of view was so evident that other nations took the hint and introduced them into their military and naval services. Since then

their use has been extending, more, probably for ship use than for use on shore, though they are employed considerably also in forts guarding the approach to harbors, to watch for the approach of hostile fleets, torpedo boats or countermining expeditions at night.

For the use of an army in the field, search-lights are mounted on suitable wagons together with portable boilers and engines, so that they can be taken on the march, moved to any part of the field, the top of a hill for instance, and employed at night whenever desired. It is clear that a search-light might often be very useful in doing such work as searching for wounded after a battle, examining the nature of the ground in a comparatively unknown country, watching the enemy when a surprise might be anticipated, guarding against a sortie from a beleaguered fort or city, etc., on many occasions; in fact, when the darkness of the night might be a hindrance to the operations of an army, or an element of insecurity.

On board men-of-war, the principal use of the search-light has been in watching for the attack of torpedo boats; but the experiments in Bantry Bay last July, showed that it was often useful in detecting the approach of hostile ships, in aiding the sighting of guns at night by bringing the target out clearly, and in embarrassing the operations of a torpedo boat or ship in trying to force a passage up a channel by dazzling the eyes of the enemy one instant and leaving them in total darkness the next.

It was related that in Africa, some three years ago, an attack on a fort was frustrated by a single search-light. The barbarians advanced to the assault brave and determined under cover of darkness, but were suddenly terrified by finding themselves enveloped in an aweful and miraculous light, which turned night into day. Halting for an instant, they covered their eyes to shield them from its dazzling whiteness; then suddenly turned and fled in panic.

But even had they not been barbarians, even had they been trained soldiers of a highly civilized people, how bewildered they would have been to find themselves suddenly in such a brilliant light that their eyes were blinded so that they could not see to pick their way; and then in a few seconds, just as the pupils of their eyes had contracted under the influence of the light, to find themselves suddenly in total darkness! Such alternations of

dazzling light and black darkness would render the march of an attacking force over a broken country towards a fort a very difficult undertaking; for it should not be forgotten how dependent we are upon our eyes, for our most simple actions, and how much our eyes assist us even in the dark. It may be pointed out here, that the search-light, like all other military instruments, must be used with judgment. It should not be used for instance, when it is important to keep your position secret from the enemy, unless the advantages of observing him outweigh the disadvantage of disclosing your own position; or unless you can immediately extinguish your light, and change your position. In order to use the search-light effectively on board ship, there should be four on each side of the ship. Search-lamps are of much higher power than any other lamps that have ever been made, and the effect of the white cylinder of light, as it touches up the different points of the land or sea over which it is made to rapidly pass, is striking and beautiful in the extreme. The people of Philadelphia may remember the naval search-light, which I used to illuminate the city last autumn, and do not have to be assured of its power and beauty. The best idea that I obtained of its illuminating effect was had one night, when I went to the tower of the Pennsylvania Railroad Depot, and watched the light stationed at the Electrical Exhibition building, on Thirty-second Street. The ray of light, when turned at right angles to my direction, looked like a silver arrow going through the sky; and when it was turned on me, I could read the fine print of a railroad time-table at arm's length.

For signaling at night, incandescent lights and search-lights both have been used, the search-lights being employed to reach long distances, or to reach points hidden by hills or other intervening objects. In using the search-light in this case, the beam is thrown into the sky, and signals are made by showing long and short flashes, or by interrupting the beam in accordance with any preconcerted code. Flashes from the search-light, which I had at the Electrical Exhibition last autumn, were seen from a distance of thirty miles.

In using incandescent lamps for night signaling, the simplest way is to arrange a key-board with keys marked with certain numbers, indicating the numbers of lamps arranged in a prominent position, which will burn while that key is being pressed. If it be

desired to signal the number 5348, for instance, meaning, let us suppose, "prepare to receive a torpedo attack," it is only necessary to press in succession keys marked 5, 3, 4 and 8, and the light of 5, 3, 4 and 8 lamps will successively blaze out and expire. Other codes, of course, can be used; the Morse code, for instance, in which a dash can be denoted by two lamps and a dot by one. One lamp could, of course, be used; the dot being denoted by a short flash, and a dash by a long flash, but it is found best practically not to use time intervals in optical telegraphy.

Electric lights have been used considerably of late in photographing the bores of great guns. Views can be thus obtained of any part of the bore, showing whether the gun has been accurately bored and rifled, and showing how the metal is standing the erosion of the powder gases.

One of the needs arising in modern warfare is means for handling heavy ordnance with speed and precision, and for bringing up ammunition. Guns, carriages and ammunition have increased so much in weight, that it has become more difficult to handle them quickly than it used to be, and yet the speed of ships has so increased that there is more necessity for handling them quickly. The electric motor will certainly be used for handling ordnance on board ships not very heavily plated with armor, for it is clear that a small wire is a much more convenient way of conveying energy to a motor of any kind, and is much less liable to injury in action than a comparatively large pipe for conveying steam, compressed air, or water under pressure; and, besides the electric motor is the ideal engine for work on board ship by reason of its smooth and silent motion, its freedom from dirt and grease, the readiness with which it can be started, stopped and reversed, and its high efficiency.

Col. Hamilton, U. S. A., says that in forts heavy guns must be worked by dynamo-electric machinery, since some other power than manual power must be employed, and since electricity is better than steam, compressed air, or water under pressure, because it can be conveyed from a central source by a single wire. Now in forts it is clear that the dynamos for search-lights, and incandescent lights and for generating power for the electric motors for handling the guns, could be placed in a well-protected spot, and the wires leading therefrom could pass to the guns through under-

ground pipes where they would be well protected from projectiles; and the guns could be pointed in any desired direction with speed, silence and precision by the simple turning of a lever or the moving of a switch.

It is probable that in the near future every man-of-war and every fort will be fitted with a complete "electrical system," well-protected from projectiles, which will include dynamos capable of supplying a very large amount of electrical energy to a system of mains, from which all the incandescent lights, all the search-lights and all the motors of different sorts can draw the supply of energy requisite for their needs.

Electrical launches have been tried abroad to some extent, and with results which, though not completely satisfactory, give promise of success in the future These boats are propelled in the same way as other boats; that is, by a propeller revolved by an engine, except that the engine is an electrical engine instead of a steam engine, the electrical engine drawing its power from what are called storage batteries carried in the boat. These storage batteries are first charged by a dynamo ashore or on board ship, and then are capable of rendering up to the motor the electrical energy stored in them, so that the motor is made to revolve and thus cause the revolution of the propeller and the advance of the boat through the water. These electrical launches have carried hundreds of persons, and have made a speed of about eight knots per hour, and the electric engine has worked perfectly well, but there has been considerable trouble with the storage batteries. Now these storage batteries are improving every day, and as their defects do not now seem irremediable, and as many electricians are devoting study and experiment to them, we may hope that storage batteries will soon be efficient and durable. This done, the electrical launch will certainly replace the steam launch in warfare, by reason of the quickness with which an electrical launch can be got ready, as there are no fires to be lighted and above all by reason of the noiselessness of the electric motor, and of the fact that in an electrical launch no flame ever flares up above a smoke pipe. With steam torpedo boats this flame frequently betrays them; that is, if the noise of the exhaust has not already done so. In using electrical launches in warfare, two sets of storage batteries will of course be necessary, so that one set can be replaced by another, and used while the first set is being recharged.

A novel application of electricity has recently been made in what have been named "electric sights." It is well known that it is difficult to get a sight at an object in the dark; (1.) because the object itself cannot be distinctly seen, and (2.) because the front sight of the gun cannot be distinctly seen. Now M. Gaston Trouvé has recently invented an electric sight no larger than the ordinary front sight of a musket, which consists simply of a filament of fine wire in a glass tube covered with metal on all sides save at the back. It looks much like an ordinary sight except to a man looking along the barrel towards the back of the lamp. But a man so looking, sees a fine incandescent wire. The battery is said to be no larger than a man's finger, and to be attached to the barrel near the muzzle by simple rubber bands, so arranged that the act of attaching the battery to the barrel automatically makes connection with the sight; and so arranged also that the liquid of the battery is out of action except when the musket is brought into a horizontal position for firing.

To throw a good light upon the target, the same inventor has devised a small electric lamp and projector, which is placed on the barrel near the muzzle by rubber bands, the battery being held at the belt of the marksman, with such connections that the act of pressing the butt of the musket against the shoulder completes the electric circuit, and causes a bright cylinder of light to fall on the target, thus bringing it out into strong relief and enabling the marksman to get as good a shot as in the day-time.

An application of electricity coming somewhat into use abroad in Continental armies is in connection with ballooning, which has received there the benefit of considerable attention and experiment. It is well known to all here that balloons have been much used for observing the movements of the enemy from a distance, and now it is reported that not only have balloons been successfully fitted with telephones for communicating at once to persons on the ground the nature of the information gathered, but also with small search-lights by which the ground can be illuminated for a considerable distance at night and the enemy's manœuvres discovered.

Incandescent lamps have also been sent up in small translucent captive balloons and under small ordinary captive balloons, and signals have been transmitted to a distance by making and breaking the current according to a preconcerted code.

Still another way in which electricity will undoubtedly be used in any future war between civilized powers, is, in boats which go beneath the surface of the water, to attack ships below the water-line. Though it cannot be said that submarine boats have ever yet been successful, still they are being improved and men have always been found willing to risk their lives in them. Some have been devised of late years in which the propelling power is electricity derived from storage batteries. In submarine diving, the telephone has been used with success in maintaining constant communication between the diver and his attendants above water, and the incandescent lamp suitably protected has also been lowered into the water to light him at his work. Submarine diving will certainly play a part in future wars, the diver descending to cut an enemy's torpedo-cables, or to inspect or repair damages to submarine wires or to ships.

Progress has been made in what have been christened "electrical guns," in which the cartridge contains an electric fuze which is ignited by pressing an electric push-button on the gun, instead of containing the ordinary percussion primer, which is struck by a hammer or bolt when the trigger is pulled. At present, this invention has not reached the practical stage, and the necessity for a battery to fire the cartridge is decidedly an objection. Yet we should remember that the battery required is very small, that it needs very little care, and that it will last a long time. We should also note that an electric gun possesses the great advantage that a better aim can be got with it than with one fired by a trigger, for the reason that the hard pull of the trigger causes a movement of the barrel, except in the hands of the most highly skilled marksman. Now, this hard pull of a trigger is a necessity, since the hammer or bolt must have considerable mass, in order that it may be strong enough to strike the primer with sufficient force to explode it; and having considerable mass, it must have necessarily considerable inertia, so that it needs a deep notch in order to hold it firm at full cock when jarred, and this deep notch necessitates a strong pull on the trigger. But with an electric gun, the circuit-closing parts can be very small and light, and can be put into a recess in the butt of the gun, out of the way of chance blows, so that when it is desired to fire, a very light pressure of the finger is all that is needed, and yet from the small inertia of

the parts, a sudden shock will not cause accidental closing of the circuit and firing of the gun.

We have now taken a running survey of the uses of electricity in war, and we find that they include nearly all the uses to which electricity can be put. Warfare now means more than the mere handling and provisioning of troops and ships; it means in addition the intelligent employment of scientific instruments. Particularly is this the case with naval warfare, for a modern ship, considered as a whole, is in itself the most elaborate, complicated and powerful machine existing.

Science has made warfare a greater thing than scientists themselves foresaw, for, it has put into the hands of our naval and military commanders, weapons surpassing in power and length of reach the fabled weapons of mythology. Yet our wonder and admiration at what has been accomplished pale before our wonder and admiration at what will surely be accomplished. Progress is marching with rapid steps. Looking forward to the future with the light the past affords us, we see the promise of great things to come. Let us welcome each new triumph of the discoverer and inventor, and take advantage of every resource that science can suggest. War is a sad necessity, but it comes seldom to a nation known to be prepared. Let us thoroughly prepare ourselves, then if war does unfortunately come, we need not fear the issue.

DECOMPOSITION OF DIDYMIUM.—Dr. C. A. von Welsbach appears to have discovered that the "dyad or triad element" didymium with an "atomic weight" of 48, or 96, or 147, according to the text books employed, and which since its separation by Mosander, in 1841, has been investigated by Marignac, Hermann, Watts, Bunsen, Deville and Erk, not to mention many others, is no element at all, but is built up of two substances, which can be separated from each other by an ordinary chemical process. The "decomposition" was in fact effected by means of the double ammonium or sodium nitrates in presence of lanthanum salt. The colors of the salts of the two substances are quite different. The salts of that which approaches lanthanum in its chemical characteristics are of a leek-green, those of the other substance are rose, or amethyst red, and it is this substance which exists in greatest quantity in didymium. Dr. von Welsbach proposes for these two new substances the names of "praseodymium" and "neodymium." It will be readily seen that from the chemical point of view alone these results are of very high interest.—*Chem. Zeitung; Nature, Sept. 10, 1885.*

COAL-TAR DISTILLATION.

By Prof. Samuel P. Sadtler.

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To the mind of the superficial or uneducated man, coal suggests only a most convenient and compact form of fuel. He may be aware that there are some differences in the several varieties that meet his observation, but probably knows only that one is more compact than the other, or that one burns less freely than the other. But the chemist, or the man of practical education, recognizes a wide reaching and fundamental difference. Leaving out of sight the theories as to the origin of coal and the successive stages in the alteration of the original vegetable tissue, he knows that a coal, with a large percentage of its carbon combined with hydrogen in the form of volatile hydro-carbons, is a very different material, both in its behavior and its possibilities, from the coal which contains little volatile matter, and whose carbon is what is known as "fixed carbon." In other words, he knows the distinction between bituminous and anthracite coal, and can at once decide in a general way at least on the possible industrial applications of each.

Let us confine ourselves for this evening's discussion exclusively to the former, and to some of the industries both present and prospective that connect themselves with it. Bituminous coal (using the word in the widest sense to include all coals having over about twelve per cent. of volatile matter) may be used, without treatment, as raw coal for fuel in domestic use, or, in the case of certain varieties, even in the iron blast furnace, but by far the larger amount is heated in some sort of retort or oven, out of access of air, with a view of driving off its volatile matter and leaving the fixed carbon, which is then known as coke. This process is termed "destructive distillation." It may be carried out with primary reference to the solid residue of the process, as in the making of coke for metallurgical use, or with reference to the collecting of the gaseous portion of the volatile matter, as in gas works. As yet, the condensable portions of the volatile matter are only obtained as side-products, or "residuals," in connection with the production of one or the other of the two materials, the gaseous, or the solid pro-

ducts. In this country, indeed, only in connection with the production of the gaseous products of the distillation.

It is of this third class of products of the destructive distillation of bituminous coal, much more complex and, perhaps, for that reason much less known than the other two classes, that we wish particularly to speak this evening. This mixture is known collectively under the name of "coal-tar." That it is a complex mixture, I have already stated. That it is a very variable mixture, may also be averred with entire safety. This will be readily understood when we come to look at the wide variation in the composition of the crude material which is submitted to distillation, viz., the different varieties of bituminous coal, and consider also the varying conditions as to temperature, method of applying heat, size and shape of retorts, admission or perfect exclusion of air, and perfection of condensing apparatus under which distillation may be carried out.

Before speaking of the processes of distillation and the characters of the tars obtained, it will be well to set before us the composition of some of the best known and most extensively used varieties of bituminous coal. The following tables show some of the typical American gas coals, coking coals, and non-coking or block coals. The analyses are taken largely from the publications of the Second Geological Survey of Pennsylvania:

I. Gas Coals.

	Westmoreland Coal Co.			Penn Gas Coal Co.		
	South Side Mine.	Foster Mine.	Larrimer, No. 2.	Irwin, No. 1.	Irwin, No. 2.	Sewickley.
Water at 225°,	1·410	1·310	1·560	1·780	1·280	1·490
Volatile matter,	37·655	37·100	39·185	35·360	38·105	37·153
Fixed carbon,	54·439	55·004	54·352	59·290	54·383	58·193
Sulphur,	·636	·636	·643	·680	·792	·658
Ash,	5·860	5·950	4·260	2·890	5·440	2·506
	100·000	100·000	100·000	100·000	100·000	100·000
Coke per cent.,	60·935	61·590	59·255	62·860	60·615	61·357
Fuel ratio,	1 : 1·47	1 : 1·48	1 : 1·38	1 : 1·67	1 : 1·42	1 : 1·56
	McCreath.	McCreath.	McCreath.	McCreath	McCreath.	McCreath.

II. Coking Coals.

	Connellsville, Frick & Co	Bennington, Cambria Iron Co.	Broad Top, Barnet.	Broad Top, Kelly.	Cumberland.	Huntingdon Co., Alloway Colliery.
Moisture,	1·260	1·400	. . .	. . .	1 10	·250
Volatile matter,	30·107	27·225	16·00	19·68	15·30	14·510
Fixed carbon,	59·616	61·843	74·65	71·12	73·28	77·042
Sulphur,	·784	2·602	1·85	1·70	1·23	1·338
Ash,	8·233	6·930	7·50	7·50	9·08	6·860
	100·000	100·000	100·00	100·00	100·00	100·000
Coke, per cent.,	68·63	71·375	81·	78·	83·59	85·24
Fuel ratio,	1 : 1·98	1 : 2·27	. . .	. . .	1 : 4.78	1 : 5·30
	McCreath.	McCreath.	T. T. Morrell.	T. T. Morrell.	McCreath.	McCreath

III. Non-Coking Coals. (Block Coal.)

	Mercer Co., Pa., Sharon Coal.	Youngstown, O.	Mercer Co., Pa.	Straitsville, O.	Brazil, Ind.
Moisture,	3·79	3·60	3·80	. . .	. . .
Volatile matter,	35·30	32·58	25·49	36·50	40·15
Fixed carbon,	53·875	62·66	68·03	55·60	57·20
Sulphur,	·675	(·85)	1·04	·96	·75
Ash,	6·36	1·16	1·70	6·94	1·90
	100·000	100·00	100·06	100·00	100·00
Coke, per cent.,	60·91	. . .	. . .	61·	58·
	McCreath	Wormley	Jno. Fulton	Wormley	Prof. Cox

It is unfortunate for the full discussion of the result of destructive distillation, as applied to these coals, that the percentage of nitrogen was not determined in all these cases, but it probably ranges between 1·3 and 1·6, and would perhaps average 1·5 per cent. An ultimate analysis of the Hocking Valley block coal, taken from the Geological Survey Report of Ohio, gives the following figures:

Carbon,	77·88
Hydrogen,	6·56
Nitrogen,	1·51
Oxygen,	10·57
Sulphur,	0·64
Ash,	2·84
	100·00 (Lilienthal)

Ultimate analyses of English coals will be given later on. Now, as to the effect of destructive distillation upon crude materials of the composition just shown. If we take what are distinctively called gas coals, their composition is not very widely different. Are the products of the distillation of coal, therefore, uniform? With regard to the solid residue, fairly so. The coke does not differ notably when the distillation has been carried to completion. With the gaseous products, there is much more difference, both in composition and amount obtained. But, with the liquid or condensable products, the results are the widest in their divergence. Probably the chief factor in producing the differences is heat. To understand this, a brief consideration of the chemical principles involved in the decomposition of the crude material and the formation of the best known of the products obtained is desirable.

From a most valuable monograph upon "Destructive Distillation," by Prof. Edmund J. Mills, of Glasgow, the following fundamental statements of theory are taken: "The process of decomposition by means of heat is most completely realized in the sun's atmosphere, which consists of the resolved weights of our common elementary and perhaps some more simple bodies. At the next lower temperature, that of the voltaic discharge, hydrogen unites with carbon to form acetylene, and with oxygen to form water. From these two products, most organic bodies can be obtained by synthesis; benzene, for instance, by keeping acetylene for a long time just below a red heat; naphthalene, by passing a stream of benzene, or one of its homologues, through a red-hot tube; ethylene, by hydrogenating acetylene; alcohol, by hydrating ethylene. Hence, naphthalene, hydrogen and acetylene, with less benzene, are found in coal-tar products when a very high temperature is used; at a red heat, they are absent, more benzene and chrysene being found. At a very high temperature, the products from coal

and shale are carbon and carbonized gases of low illuminating power, with but little liquid distillate; at a low temperature, there is much liquid product and gas of high illuminating power. The greatest amount of liquid product of low-boiling point is found in American and Russian petroleums, which have probably been produced by the long-continued application of a very gentle natural heat."

To show the verification of these principles in practice, the results of high and low temperature distillation upon the same gas coal, may also be quoted from the same authority:

		High Heats.		Low Heats.	
Volatile Matter.	Gas,	20·49		6·49	
	Ammonia water,	3·09		7·24	
	Tar or oil,	17·08		26·45	
	Sulphur,	0·29		. . .	
	Water, at 212°,	4·15		. . .	
			45·10		40·18
Coke.	Fixed carbon,	45·00		49·93	
	Sulphur,	0·34		. . .	
	Ash,	9·56		9·89	
			54·90		59·82
			100·00		100·00
Practical Results.					
Gas per ton of coal at 60° F., and 30 in. Bar.,		10·415 cub. ft.		3·800 cub. ft.	
Illuminating power in standard candles by union-jet consuming 5 cub. ft. per hour at 5 inches pressure,		31·75		. . .	
Gravity of gas-air, 1,000,		·574		. . .	
Gallons of crude tar per ton of coal,		. . .		63·44	
Specific gravity of crude tar oil,		. . .		0·934	
Gallons of ammonia water per ton of coal,		. . .		16·12	
Pounds of sulphate of ammonia per ton,		. . .		1·54	

Note.—The low heat results were gotten by distilling the sample in a two-inch iron tube in a gas furnace.

Now, confining ourselves again to the tar or condensable product, does the composition of it, when considered in detail, vary less than does the relative amount produced? The normal constituents of an ordinary gas tar, which we may reasonably characterize as a high temperature tar, are shown from the following examples:

The average quantitative composition of London and Berlin gas tars is given on the authority of Schultz,* as follows:

LONDON GAS TAR.

Benzol of 50 per cent.,	1·1
Solvent naphtha,	1·0
Burning naphtha,	1·4
Creasote oil,	33·2
Thirty per cent. anthracene,	1·0
Pitch,	58·6
Loss,	3·7
	100·00

BERLIN GAS TAR.

Benzol and toluol for anilines,	0·8
Bright (solvent) oil,	0·6
Crystallized carbolic acid,	0·2
Creasol (disinfecting quality),	0·3
Naphthalene,	3·7
Anthracene (pure),	0·2
Heavy oil (for impregnating timber)	24·0
Pitch.	55·0
Water and loss,	15·2
	100·00

Tars such as these are gotten in the ordinary course of gas making, where the temperature averages 2,000° F. How is it in low temperature tars? Unfortunately, no analyses of the low temperature tar quoted before from Mills is given. We must take then the Jameson coke-oven tar, to be spoken of later, as our typical low temperature tar. Dr. Watson Smith, who has given it a thorough chemical study, states† that benzene is quite absent from it, although, in admixture with paraffins, both very small quantities of toluene and larger quantities of xylene are present, as he obtained their nitro-products; that in its light fraction, "the bodies present belong to the marsh gas series mainly;" that "the chief bulk of the Jameson tar, having a sp. gr. of 0·960, consists of oils boiling between 250° C. and 350° C., from which on cooling no crystalline substance separates;" that "a considerable proportion of oil distils over above 350° C., viz., from somewhere above 400° C. to

* Schultz, Chemie des Steinkohlentheers, pp. 95 and 96.

† Paper read before British Association, at Southport, September 24, 1883.

the point at which pitch remains in the retort, and these oils separate paraffine scale and the paraffine wax obtained has a high melting point, viz., 58° C." Again, "if the crude oils boiling between 200° C. and 300° C. be treated with caustic soda lyes, and the phenols extracted in the usual way, a fairly large proportion of a peculiar series of phenols of increasing boiling points is obtained in the crude extract, certain of these phenols resembling the constituents of the creasote of wood-tar. A mere trace of carbolic acid was found, but more of the cresols, and by far the largest bulk of the constituents of the crude phenol distils at from 250° C. to 300° C. The latter fraction, boiling at about 300° is a resinous substance perfectly soluble in caustic soda, to which it communicates a red color." "Neither naphthalene nor anthracene are present, even in traces, in Jameson's coke-oven tar." "The fact that the specific gravity of this tar is less than that of water is a circumstance sufficient of itself to indicate that it belongs to the class of tars obtained by the distillation of coal at lower temperatures."

With this low temperature tar may also be contrasted a high temperature coke-oven tar. Such is found in the Simon-Carvés tar, to be spoken of, too, later. The temperature here even rises beyond that of the gas retorts, being 2,200° F., and with the newer recuperative ovens 3,000° F. Watson Smith (*loc. cit.*) finds that "the Simon-Carvés tar is quite different both in appearance and specific gravity from Jameson's; its specific gravity is 1·20, and it is black and thick and smells quite differently from the Jameson product; the former therefore sinks at once in water, whilst the latter floats on the surface. In composition, the tar from Carvés ovens closely resembles the tars produced in the large London gas works, *i. e.*, it is exceedingly rich in naphthalene and anthracene, but less rich than some, *e. g.*, the Lancashire tars in benzene, toluene, xylene and carbolic acid; but these it contains as richly as any London tar. It is, moreover, quite free from paraffine. This great difference in the Simon-Carvés tar from that of Jameson is due to the fact, that in the production of the former, a close oven, a very high temperature, and a rapid distillation are adopted, just as is the case in the gas works.

A second very important factor in determining the results of destructive distillation, inferior only in value to that of temperature,

is the presence or absence in the retort or oven of large surfaces of incandescent porous solids, such as coke or firebrick. These, taken in connection with high temperature, seem to have a very great influence in determining the formation of such constituents as naphthalene and anthracene. Thus Atterberg, (*Berichte*, 1878, p. 1222), passed Swedish wood-tar through iron tubes *filled with coke*, heated either to dull or to bright redness. The product obtained at a bright red heat contained all the essential constituents of coal-tar, it was rich in naphthalene, contained a fair amount of anthracene, but only small quantities of phenols, and about seven per cent. of benzene and toluene. At a dull red heat, fifty to sixty per cent. of the tar escaped unchanged; naphthalene could not be discovered in the product and only 0·3 per cent. of anthracene was detected by the chromic acid method; ten per cent. of toluene, containing but little benzene, was obtained and higher phenols, with but little phenol itself. Letny, (*Berichte*, 1878, p. 1210), whose results were published in Russian, in 1877, made experiments on a large scale in a retort 7 feet long and 1 foot across, with Baku petroleum residues (sp. gr. 870; boiling point, 270° C.) which were led over red-hot charcoal. Tar, equal to about forty per cent. of the petroleum, was obtained of the following composition (sp. gr. 1207):

Below 200° C.—13·9 per cent. { 2·3 per cent. water. / 4·6 per cent. benzene below 90° C / 5·2 per cent. toluene, etc., 90°—145° C.

From 200° to 270°—26·9 per cent. / From 270° to 340°—8·6 per cent. { Naphthalene and unchanged petroleum.

The portion boiling above 340° C. was collected in three fractions.

(*a.*) 12 per cent. { 9·3 per cent. petroleum. / 2·7 per cent. crude phenanthrene. / ·76 per cent. pure phenanthrene.

(*b.*) 7·5 per cent. { 5·2 per cent. petroleum. / 2·4 per cent. crude anthracene. / ·8 per cent. pure anthracene.

(*c.*) 8 per cent. { 6·04 per cent. petroleum. / 1·94 per cent. crude anthracene. / 1·5 per cent. pure anthracene.

Besides tar, a mobile liquid was obtained, consisting of benzene, toluene, xylene, and naphthalene, almost free from bodies of higher boiling point. Letny therefore attaches great importance to the presence of porous carbon, and states that the quantity of solid hydrocarbons produced is greater in proportion as the layer of car-

bon through which the vapors must pass is thicker. Letny's process was carried out later on a large scale at the Ragosine refinery at Kasan on Russian petroleum residues, and by the firm J. G. Geigy, of Basel, on American petroleum residues in their branch factory at Cleveland, O., and samples of the benzene and anthracene from this source were exhibited at the Swiss National Exhibition, at Zurich, in 1883. The firm of Nobel Brothers, the great Russian petroleum producers and refiners have also carried out on a large scale similar experiments and get from *astatki*, or Russian petroleum residues, in one distillation, 30 to 40 per cent. of a tar containing from 15 to 17 per cent. of 50 per cent. benzene. By a second destructive distillation of the heavy oils remaining in the tar after the separation of the benzene, 70 per cent. of tar is obtained containing from 7 to 10 per cent. of 50 per cent. benzene, 16 per cent. of naphthalene, 2 to 3 per cent. of dry "green grease" (or 30 per cent. anthracene) and 24 per cent. of pitch. Having shown that the coal-tar obtained in the processes of destructive distillation may vary both as to quantity and as to quality, through quite wide limits, according to the conditions under which the distillation is carried out, let us look at methods at present in use for its production. As I said before, in no process carried out on a commercial scale is the production of the condensable liquid products of destructive distillation the primary object. They are only "residuals" as yet. As Prof. H. E. Armstrong well remarks in a recent paper,* "It is not a little remarkable that an industry of such magnitude and importance should so long have been without the chemist's guidance, especially as the progress of chemistry has received such an impetus from the study of coal-tar constituents. The distillation of coal has been left to the engineer. Attention has been directed almost solely to the production of gas. Now that other products than gas are claiming attention, it is high time that the problem should be studied in a systematic and scientific manner, and that the chemist, and not the mere analyst, should find a place in the coke and gas works." The methods of destructive distillation in connection with which the tar and ammonia water are condensed and collected, may be summarized under five heads: (1.) In the manufacture of illuminating gas; (2.) In the coking

* Journal of Society of Chem. Ind., Sept. 29, 1884, p. 467.

of coal; (3.) In blast furnace working with raw bituminous coal; (4.) In gas producers including regenerator and water gas methods; (5.) In the distillation of petroleum residues and the production of oil gas.

The methods of manufacture of illuminating gas from bituminous coal need not be described here. We have already spoken of the chemical principles involved and shown that the results, as far as the production of tar is concerned, may vary through rather wide limits according to the conditions of temperature, etc. The methods of separating the constituents of the crude tar of the coal gas manufacture will only be considered in their general outlines, as a detailed account of them would take up considerable space and have a special, rather than a general interest.

The crude tar, if possible, is run while hot from the tar wells direct to the stills, or if the distance does not allow of that, the crude tar is warmed in suitable vessels by coils of steam-pipe, so as to effect a more perfect separation of the tar from the ammonia water. The more of this held mechanically in the tar, the more troublesome the distillation in its first stages on account of the frothing caused by the irregular development of steam in the body of the tar. The first condensable portion, known as "first runnings," has a sp. gr. of 0·78 to 0·85, and, according to the character of the tar, constitutes from two to four per cent. On standing, this distillate separates into two layers, one of ammonia water and the other of very volatile oil (benzene spirit), which are easily separable. On strengthening the fire somewhat, there now comes over the "light oil," with a sp. gr. of 0·83 to 0·89. It amounts to from seven to eight per cent. of the tar, and consists chiefly of benzene and its homologues, but contains in addition phenol, cresols, naphthalene, and basic compounds. In those establishments, in which the distillation is controlled by the thermometer, the light oil fraction is run until 210° C. is reached. Between 210° C. and 400° C. is obtained the "heavy oil" or "dead oil," so-called, because it sinks under water. The first portions of this contains much naphthalene, so that it becomes crystalline on cooling. On farther distillation, the consistence is again thinner and finally the distillate remains liquid on cooling. It now contains phenol, cresols, and bases and hydrocarbons of high-boiling point. After a time, the oils become thick again and crystallize on cooling. This is due this time not to naphthalene, but to anthracene,

and its accompanying compounds, phenanthrene, carbazol, acetnaphthene and fluorene. The portion from 210° to 300° C. is usually caught separately under the name of "creasote oil," and that from 300° to 400° C., which is generally green colored and hardens on cooling as "anthracene oil," or *green grease*. The percentage of heavy oil of the first kind is from 32 to 35 and from 10 to 11 of anthracene oil, containing 10 per cent. anthracene. The residue of this distillation forms what is called pitch. This is run out while yet fluid and hardens to a lustrous mass, breaking with conchoidal fracture. According to the degree to which the distillation has been pushed, the pitch differs, being either soft pitch or hard pitch, known too as "carbon black." The working up of these crude fractions for the extraction of the constituents in a state of purity, we will not enter upon in this paper.

The second class of methods of destructive distillation, with accompanying tar production, before referred to, was in connection with the coking of coal. Under this head, we have to notice some results of very great interest, from both a practical and a scientific point of view. The burning of coke in pits, "meilers," or mounds, represents the first rough and wasteful method of converting bituminous coal into coke. It involves the total loss of all the volatile matter of the coal, and the pouring into the surrounding air of large amounts of black, sulphurous smoke, or the products resulting from its combustion. It allows, however, of the smothering the finished coke with fine dust, instead of requiring it to be quenched with water, as in other methods. The so-called "beehive" ovens, allow of the volatilizing of a much greater amount of the sulphur in the coal, and give a decidedly increased yield of coke over the pit-burning method. The charge can be run over, too, in less than half the time. Some air is admitted in both cases, and thus some coke is burned, and no attempt is made to save residuals in either case. In the various forms of ovens, known collectively as Belgian ovens, and including the Appolt and the Coppée ovens, no air is admitted into the coking space, but into the side flues, so as to mix with the gaseous products passing through openings in the oven walls into side flues. Thus, complete combustion of all the products is insured, and the ovens are heated thereby. No coke is burnt, the yield is therefore larger, but there is some doubt as to the quality being

as good as that from the beehive oven. The first coke ovens, that allowed of the recovery of the volatile products, were the Knab ovens, worked at St. Denis, near Paris, in 1856, and the Pauwels-Dubochet ovens, worked at Saarbrücken, in 1854. The Knab ovens were modified by Carvés, a French engineer, at St. Etienne, to whom, probably, belongs the credit of first constructing an oven for making coke with the simultaneous collection of the gas, coal-tar, and ammonia water. Passing by the many French and German patents that followed for new ovens and modifications of older ovens, looking to the collection of residuals, and referring for full information on this matter to the very elaborate historical paper, by Dr. Watson Smith, on the subject, (in the *Journal of the Society of Chemical Industry*, for December 29, 1884), we come now to the two forms of coke ovens that are at present

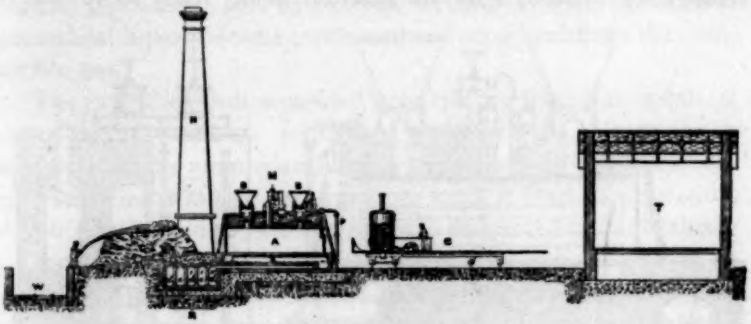


FIG. 1.

A. Coke oven.
BB. Tubs for conveying coke to ovens.
G. Steam ram for thrusting coke out of oven.
C. Coke as thrust out of oven, and man supplying water to cool it.
W. Railway where coke is put into wagons.
S. Main combustion flue.
R. Recuperator, consisting of hot air flues *d d d*, and smoke flues *e e*.
P. Pipe for return gas.
M. Main through which gases are drawn by exhauster.
T. Exhauster and pump house
H. Chimney for twenty-five ovens.

dividing the attention of practical and scientific men in England, where the subject is now more actively agitated than in France or Germany. These are the Simon-Carvés oven and the Jameson oven, both of which have now been in use on a large scale for several years.

The principles of the Simon-Carvés oven, which is the newer and improved form of the older Carvés oven, may be gathered from the illustrations in *Figs. 1* and *2*, and from the statements made by Mr. Henry Simon, C. E., of Manchester, the English patentee, in his address before the Iron and Steel Institute, in 1880. "According to our system, the coal is rapidly carbonized, by sub-

jecting a comparatively thin layer of it to a high temperature in a closed and retort-like vessel, and, whilst in the beehive ovens the volatile products are burned inside, we burn them around the outside of this retort-like vessel, and only after they are deprived of the tar and ammoniacal liquor. Each oven is in the form of a long, high narrow chamber of brick work, and a number of these are built side by side, with partition walls between them sufficiently thick to contain horizontal flues. Flues are also formed under the floor of each oven, and at one end of these is a small fire-place, consisting of a fire-grate and ash-pit, with suitable door, the fire-door having fitted above it a nozzle, through which gas produced from the coking is admitted to form a flame over some fuel burning on the grate. Only a very trifling amount of such fuel, consisting exclusively of the small refuse coke is used here, its function being really more that of

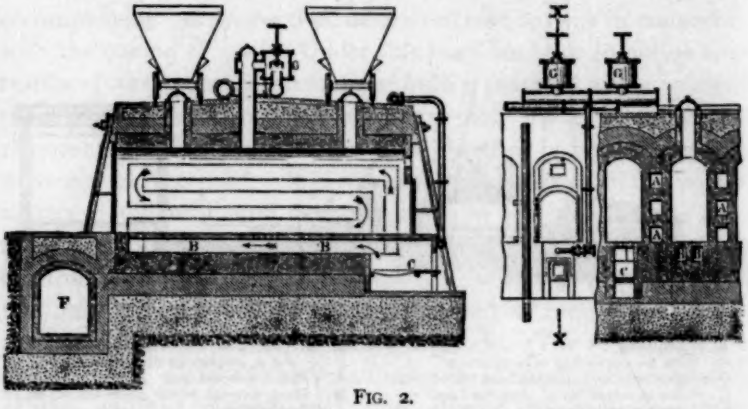


FIG. 2.

igniting the gas than that of giving off heat. These grates are not charged with fuel more than twice every twenty-four hours when in regular work. The products of combustion pass from the fire-place along a flue under the oven floor to the end farthest from the fire. They return along another flue under the floor to the fire end; they then ascend by a flue in the partition wall to the uppermost of several horizontal flues formed therein, and *descend* in a zigzag direction along these flues, finally passing into a horizontal channel leading to a chimney. Thus the coke oven is heated, not only at the bottom in the usual manner, but also evenly at the sides, and the coal with which it is charged becomes rapidly and

completely coked. No air is allowed to enter our ovens, which in reality are closed vessels, with the exception of the opening for the escape of the volatile products. The improved ovens are fed with coal by openings in the roof, over which coal trucks are run on rails; and the coal is evenly distributed by rakes introduced at end openings, provided with doors faced with refractory material, which doors are closed and kept tightly luted while the oven is in operation. The feed holes in the roof are also provided with covers. Through the middle of the roof rises a gas pipe provided with a hydraulic valve, which closes the passage by a lip projecting down from it into an annular cavity surrounding its seating, in which it is immersed in a quantity of tar and ammoniacal liquor, lodged there during previous distillations. The volatile products of the coal distillation rise by the gas pipe, and are led through a range of pipes kept cool by external wetting, so that the tar and ammoniacal liquor become condensed and separated from the combustible gas."

"The gas, when thus separated from the condensed materials, is further passed through scrubbers or vessels containing coke moistened by the ammoniacal liquor, which on being repeatedly used, becomes stronger and stronger until it reaches saturation, when it may be run off into reservoirs to be treated in the ordinary way for the preparation of ammoniacal compounds, or sold in its crude state for the manufacture of soda by the ammonia-soda process. (All the ammoniacal liquor from the Terrenoire Works, in France, where 100 Simon-Carvés ovens are in operation, is contracted for by M. Ernest Solvay, the great manufacturer of soda by the ammonia-soda process.) All valuable bye-products having thus been withdrawn from the gas, it is led by pipes to the nozzle at the fire-places under the sole of the ovens, where it is burnt."

"When a charge is nearly finished and ready to be taken from the oven, some trucks full of coal are placed ready on the rails, going right along on the top of the ovens and over the charging holes. The two end doors are then opened. The mass of coke measuring about 30 feet long by 2 feet thick and 6 feet high is pushed out at the back of the oven and on to the bank, by means of a ram or piston worked by a portable steam engine running on rails in front. The ram can be brought opposite to each oven in turn. The coke is then quenched as usual."

A claim is made for this method of seventy-five to seventy-seven per cent. of coke to the amount of coal used. The yield of residuals, during a run of 215 days at the coke ovens of Messrs. Pease at Crook, was, on an average, 27·70 gallons ammoniacal liquor per ton of coal carbonized, and 6·12 gallons of tar per ton of coal carbonized. The selling price of the ammoniacal liquor was one pence per gallon, and of the tar three pence per gallon. The chemical character of the tar from the Simon-Carvés' ovens has been referred to already in speaking of the conditions of destructive distillation. (Sample shown.)

The Jameson process is illustrated by *Figs. 3* and *4*.

The following statement of the principles upon which it is based and of the working of the process is taken from Mr. Jameson's published papers: "The process is based upon the fact, that in the ordinary coke oven the progress of distillation and finally of

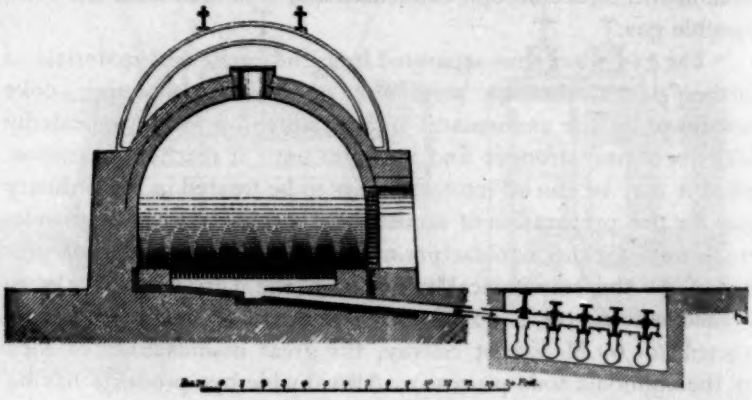


Fig. 3.

ignition of the coal operated upon is from the top downwards. If, as in the ordinary process, the products of distillation be suffered to find their way to the upper surface of the charge in the oven, the intense heat there existing and the access of air required by the process of coking at once decomposes these products and renders them valueless. If, on the other hand, the products as they are formed are caused to pass to the lower and cool surface of the charge, and are extracted from the bottom of the oven, they may be recovered quite unchanged in constitution by mere condensation. This is accomplished by making passages below the

oven floor, and laying upon these passages perforated quarles or recessed bricks, and applying gentle suction during the process of coking, by means of a pipe communicating with these passages and coupled to an exhauster."

"In the process of making coke in the ordinary oven, the rate of descent of incandescence is from half an inch to one inch per hour, and the charge of coal throughout its mass is therefore subjected in succession to a low and very gradually increasing temperature, and thus by the Jameson process the products formed at the lowest heat are obtained as they are formed, being passed immediately through the mass of cooler coal below that in which they were formed and so into the suction pipe and condenser." "An incidental effect arising in the carbonization of bituminous coal is of great importance in this view. As the coal is heated, it apparently melts together and cokes, and by this coking there is

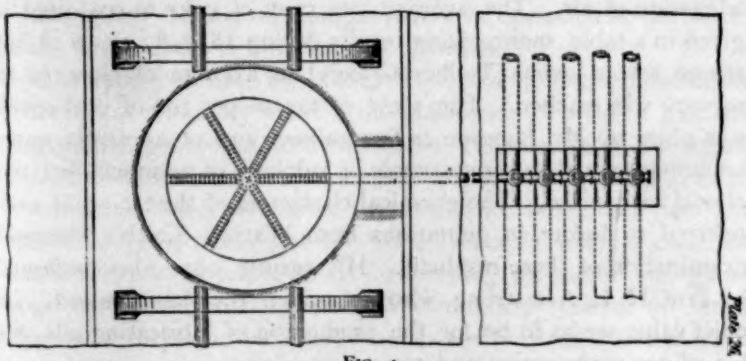


FIG. 4.

formed, at a point between the mass of incandescent coke and the raw coal, a seal or diaphragm over the whole area of the oven. Below and in the softer parts of the seal, the vapors are liberated and the harder part of the seal forms a more or less impervious shield, separating between the gases below and the gases above it, whereby, to the extent of the protection thus afforded, the one is subjected to the suction of the oven bottom, and the other is shielded from it." "Although the production of condensable products is all that can be desired, and although the incidental effect of the seal described is of great value, yet the perfection of the recovery is manifestly dependent upon the suction applied. It is clearly possible by excessive suction to break through the seal

and diminish the yield of coke, by drawing air through the charge and so burning it, and it is as clearly possible by too slight suction to make a recovery of products of almost at no value; but the range between these limits is very wide and by due proportioning of the suction with reference to the circumstances of the case it is possible to effect a large recovery of oil and ammonia with a full yield of coke of the highest quality."

The Jameson oven is in reality only an alteration of the beehive oven, involving a perforated floor, and suction pipes set in below this, and the beehive can therefore be adapted to the saving of residuals at quite moderate cost. The gas, being produced at low temperature and withdrawn as formed, is a richer burning gas than most producer gases, but the yield of coke is not so large as in the case of the Simon-Carvés' ovens, a small portion being necessarily burned at the top of the oven during the coking, because of the admission of air. The average per cent. of coke to coal used is given in a table, summarizing results during 1882–83, as 56·28, but at one set of ovens (Tudhoe Grange) an average of close on to seventy was reached. The yield of tar-oil per ton of coal coked was given by Mr. Jameson as five gallons, and of ammonia water an amount equal to three pounds of sulphate of ammonia per ton of coal carbonized. The chemical characters of the tar or oil were referred to before, in quotations from Watson Smith's chemical examination of these residuals. His results were also confirmed by Prof. H. E. Armstrong, who examined the Jameson oil. Its chief value seems to be for the production of lubricating oils, oils for oil-gas manufacture and creasoting oils.

(*To be continued.*)

Second Blooming of Catalpa.—Mr. J. Schneck writes as follows: "On one of the streets of Mt. Carmel, Ill., stand two large trees of our local native Catalpa (C. *speciosa*, Warder). During the first week in June, they were both in full bloom. These flowers all dropped during the first half of that month. To-day, July 20th, one of them is again in full bloom. The whole top is literally covered with flowers, and, at the same time, the beans of last month's flowers are hanging thick. In this second crop, the panicles are about as large and full as in the first. The flowers are of the usual size, but a little paler. It is so unusual for a second flowering to be apparently as abundant as the first, that I think it proper to report this instance. Another peculiarity is the short time between the two crops—about six weeks.—*Botan. Gazette, Sept. and Oct., 1885.*

THE PRODUCTION OF ALUMINUM AND ITS ALLOYS IN THE ELECTRIC FURNACE.

BY EUGENE H. COWLES.

[*A Paper read at the Stated Meeting of the* FRANKLIN INSTITUTE, *held January 20, 1886.*]

W. P. TATHAM, President, in the Chair.

MR. COWLES:

Mr. President, and Members of the INSTITUTE:

In order that I may give you as brief and explicit an explanation as possible of our discovery, process and inventions, I will first proceed with a description of the plant of the Cowles Electric Smelting and Aluminum Company, now in operation at the works of the Brush Electric Company, at Cleveland, O.:

The apparatus used by us for the purpose of experiment in the reduction of refractory ores for the production of metallic calcium, magnesium, potassium, sodium, silicon, titanium, and the manufacture of aluminum and aluminum-bronze and other alloys, consists of two large Brush dynamos, two resistance boxes and two ammeters, a drying pan, eight fire-brick furnaces, suitable electrical conductors and switches, hoods for carrying off vapor and gases, large carbons—3 x 30 inches—for electrodes, screens for sizing charcoal and carbon, and a large mortar and pestle and several washing vats for washing and concentrating the furnace products. Steam-power to drive the dynamos is furnished by the "Brush Electric Company." The arrangement of the plant so as to effect the reduction of the above-named metals and metaloids, by means of carbon as the sole re agent, is as follows:

The Dynamos.—These are, of course, placed in the dynamo room as near as possible to the driving shaft, where they can be kept free from any dust or grit from the furnace room. The larger of these is by far the most powerful machine ever built by the "Brush Electric Company." It weighs over 7,000 pounds, and at a speed of 907 revolutions per minute produces a current of 1575 ampères with an intensity of 46·7 volts. It is of the shunt-wound type of dynamo, built for the purpose of incandescent lighting;

further than being of greater capacity, and having a hub made of the Cowles aluminum-brass which exhibited a tensile strength of 95,000 pounds per square inch and five per cent. elongation, this dynamo does not differ from the ordinary machine.

Conduction of the Current of the Large Dynamo to the furnace in the furnace room and back to the machine, is accomplished by a complete metallic circuit except where it is broken by the interposition of carbon electrodes, and the mass of pulverized carbon in which the decomposition of the ore takes place. This circuit consists of thirteen copper wires each 0·3 inches in diameter. There is likewise inserted into this circuit an ampèremeter through whose helix the entire current flows, indicating, by its suction of a plunger armature attached to a spring balance and dial-faced indicator, the total strength of current being used.

This ampèremeter is an important element in the management of the furnace, as by the position of the finger on the dial the furnace attendant can tell to a nicety what is being done by the current within the furnace. It is placed upon a shelf in a good light, near to and in full view of a person in any position about the furnace.

Between the ammeter and the furnace in the furnace room, and forming part of the circuit, is placed a large resistance coil of german silver immersed in water, a heavy copper slide passing backward or forwards as desired, throwing more or less of this resistance into the circuit, and almost the entire energy of the current may be thus applied to heating water. The object of the resistance box is to serve as a safety appliance. It is used by the furnace operator when it is desired to change the current from one furnace to another, or if it be necessary to choke off the current almost entirely before breaking it by a switch, thus preventing serious flashing at the commutator of the dynamo or at the switch. It is likewise of value should any evidence of a short circuit appear in the furnace or elsewhere.

Thus far the apparatus that has been described, presents no novel feature beyond its great magnitude, the peculiar combination made, and the purpose for which it is used. Now, however, we will describe a device that we claim is something radically different from anything that has heretofore been known, namely, an incandescent electrical furnace for the smelting of refractory ores,

FIG. 1.

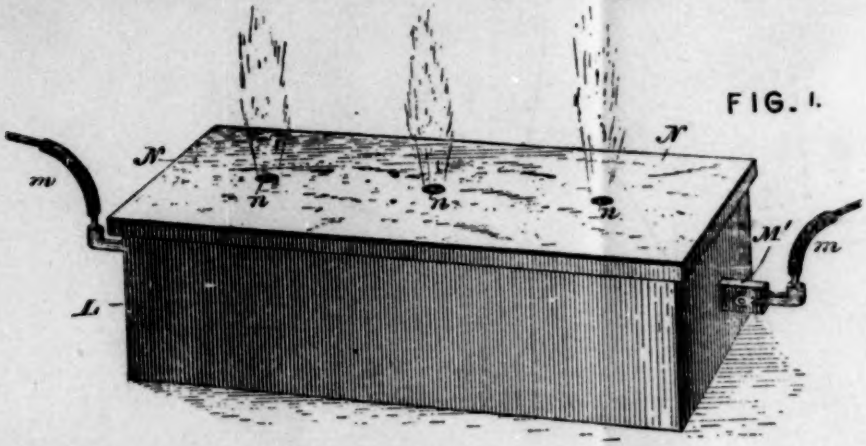


FIG. 2.

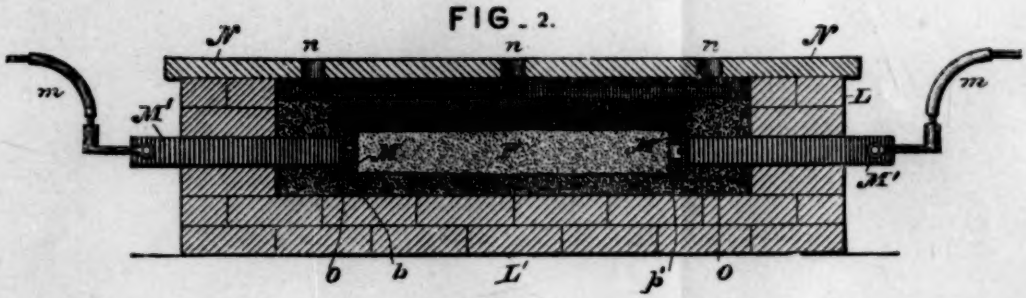
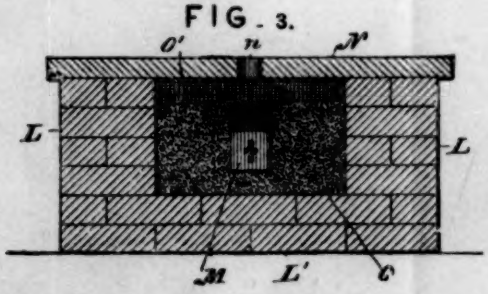


FIG. 3.



THE COWLES ELECTRIC SMELTING FURNACE.

Fig. 1. Perspective view.
Fig. 2. Longitudinal section.
Fig. 3. Transverse "
L L'. Fire-brick floor and walls.
N. Removable fire-clay cover.
n. Vents for escaping gases.
M M'. Electrodes.
m. Conducting wires to dynamos.
O. Packing of fine charcoal.
P. Charge of ore and granular charcoal.
O'. Layer of granular charcoal, covering charge on top.

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metals and compounds, and in which other metallurgical and chemical operations, impossible in the past, may now be performed with both ease and economy. This furnace as constructed to utilize the current of the large dynamo, is a rectangular oblong box of fire-brick, with walls, bottom and ends, nine inches thick. The interior space being five feet long by one foot wide and one foot deep. This is closed by a cast-iron slab or cover through which are two three-inch holes for the escape of the gases liberated during the operation. This lid may be removed at will, its own weight being all that is required to keep it in place. The walls of the furnace are designed to be air-tight. At both ends of the furnace are holes large enough to admit an enormous electric light carbon, three inches in diameter and thirty inches long. Each of these carbons is connected at the end, projecting outside of the furnace, with the positive or negative conductor as the case may be, the connection being a copper cap fitting over the end of the electrode, the same being fastened to a large and flexible wire cable which forms part of the circuit. When it is desired to charge the furnace, it is first necessary to lime it, to prevent its destruction by heat. To do this, a quantity of finely pulverized charcoal that has been soaked in a solution of lime and water, and then thoroughly dried in the drying pan, is put into the fire-brick box, enough being placed therein to cover the floor to a depth of several inches. The carbon electrodes are then pushed into the box through the end walls until the ends of the carbons are but a few inches apart. These electrodes are just on top of the finely powdered charcoal of the floor. A sheet-iron gauge or guard, parallelogram-shaped, and open at top and bottom, is now placed over these electrodes in such a manner as to form two walls on either side of the electrodes about three inches distant. Space is thus left between the sheet-iron and the walls of the furnace, and likewise for about a foot at each end of the same. More finely powdered limed charcoal is put into the furnace-box so as to completely fill the space outside the sheet-iron gauge and within the furnace walls and up to within a couple of inches of the top. The furnace is now almost entirely full of the lime-washed charcoal, except the space nine inches wide, three feet long and six inches deep in the centre of the box, and into which the electrodes project. All is now ready for the charge, which is prepared. Should

it be desired to produce aluminum-bronze, we mix sixteen or eighteen pounds of granulated copper, twelve to fourteen pounds of aluminum oxide in the form of broken çorundum, and several pounds of coarsely broken charcoal together, and burying the electrodes with the same, and thus filling the space inside the walls of the sheet-iron gauge. The gauge is then lifted from the furnace, additional coarse charcoal is spread over the entire mass, the iron top of box is put in place, the seams luted with fire clay, the current from the dynamo switched on, and the furnace is in operation in but little more time than it has taken to give these apparently trifling but very important details.

We will now proceed to make a little study of the philosophy of the process, after first watching a successful "run" or "heat" from the beginning to the close of the operation. Of course, the furnace and its contents, when the current of electricity was turned on, were entirely cold and the resistance presented to the flow of the current consequently is higher than it would be at any time during the "heat," unless some unforeseen accident, such as a slight explosion of gas, takes place. But notwithstanding that the furnace is cold, a complete metallic circuit, with carbon tips dangerously near together, is ready to convey a one hundred horse-power flash of lightning into the furnace, should a short circuit occur. *There are likewise many pounds of pure copper in between and about these carbon tips that may be melted and run together and thus produce a short circuit. With these conditions an electrician would insist that the man in charge of the furnace should look pretty sharply lest the four-thousand dollar dynamo at the other end of the wire be burned out, or somebody be injured by a heavy flash.* The man in charge, however, has anticipated such a contingency by having thrown in several coils of the resistance box, so that under no condition, even if the great carbons in the furnace were pressed tight together, would the dynamo be able to produce a current of more than 1600 ampères, the maximum load. Upon watching the ampèremeter, however, it is seen that this precaution was not necessary for only about 200 ampères are indicated as flowing, the artificial resistance is therefore slightly diminished, the needle of the ammeter moves up rapidly to 600 or 800 ampères, suddenly it gives a jump up to 1,200, then back to 200, then with a bang the armature of the am-

meter is brought against the magnet and it registers 1,600 ampères of current flowing, and then instantly drops back to almost zero.

As every jump of that needle means wear and tear on the commutator and brushes of the dynamo, care is now taken to keep more control of the current and a little more artificial resistance is thrown into the circuit. The needle now moves more slowly around the dial, gradually making fewer and fewer jumps, and at the end of eight or ten minutes, it has worked up to the 1,000 ampère mark, and becomes quite steady. Suddenly there is a hiss and a sharp report, a tongue of greenish yellow copper flame darts upwards from the hole in the furnace top and then disappears, to be followed after a minute or so by a slight vapor. This was caused by the monoxide of carbon combining with the atmosphere in the furnace to produce an explosive compound. To prevent this gas from accumulating to an extent to raise the furnace top and loosen the luting, the attendant holds a lighted stick over the vent and a series of slight explosions follow.

Soon a characteristic yellow-white flame appears, above the hole, the needle registers about 1,200 ampères of current flowing, all of the artificial resistance is withdrawn and the process of reducing aluminum and alloying it directly with copper is completely under way. Soon the needle gradually creeps around the dial to the 1,400 or 1,500 ampère mark. This is regarded as being a little too hot work for the dynamo and at the same time the plume of flame above the furnace indicates a little less rapid reduction. There are, therefore, two things now necessary. The first is to put more resistance into the circuit, and the second is to put more ore into the zone of reduction. These are both done by withdrawing one of the electrodes and the ammeter needle drops back to 1,200, and the flame above the furnace soon gives evidence of doing more work, by reason of more copious white fumes being given off.

This pulling out of the electrodes is repeated over and over again until both are out to their full length. At the end of an hour, the "heat" is completed. The current is then switched to another furnace, but one furnace being used at a heat. The artificial resistance is again resorted to, enough being thrown into the circuit gradually, thus slowly choking off the current, permitting the proper regulation of the brushes on the dynamo, and also

giving time for the engine to govern itself. Finally, at the end of several minutes, the switch is thrown open and the furnace is entirely out of the circuit. Furnace No. 2 is now operated in precisely the same manner as the furnace No. 1, which is allowed to cool off. At the end of two hours furnace No. 2 is thrown out of the circuit and work begun on furnace No. 3. By this time No. 1 is ready to be discharged. The lid is removed and water is used with a sprinkling pot to quench the fire still remaining. At the bottom of the furnace, on the floor of fine charcoal, is found an oblong metallic and crystalline mass of white metal. It is the copper charged with from fifteen to thirty-five per cent. of aluminum and a small quantity of silicon. It frequently averages twenty per cent. to twenty-two per cent. of aluminum and silicon. Covering this mass is also found a considerable quantity of fused carbide of aluminum. Analysis of this product has shown thirty to sixty per cent. of metallic aluminum present. On cooling, it forms very large and distinct crystals.

The very rich white bronze is collected together, put into an ordinary graphite crucible, and run into ingots weighing fifty or sixty pounds. These are carefully analyzed by the chemist, after which they are remelted and copper is added to them in the proper proportion to reduce them to the standard ten per cent. aluminum-bronze. To guard against mistakes being made in the analysis of the white and brittle ingots in the amount of copper added thereto, and in keeping the bronze free from impurity, every ingot of ten per cent. aluminum-bronze has its tensile strength tested, and it must show a tenacity of at least 90,000 pounds to the square inch.

As to the capacity of our large dynamo, and the economy of the process, a few figures may be interesting. In ordinary circumstances we expect to average a daily production of at least 300 pounds of ten per cent. aluminum-bronze for twenty hours' work with each machine of this size. In addition to this 300 pounds of bronze, containing in round numbers thirty pounds of aluminum, there is produced about sixty pounds of metallic aluminum in the bye-products, a large portion of which, with proper concentrating apparatus, will be cheaply reclaimed and rendered marketable. Ninety pounds of aluminum in twenty hours is a production of four and one-half pounds per hour. Four and one-half pounds per

hour produced by the energy of 120 horse-power equals the consumption of about 26·6 horse-power per hour to reduce one pound of aluminum. At times we have far exceeded this result. Indeed, two heats have been made wherein the energy consumed has been but twelve and one-half horse-power per hour per pound of metallic aluminum produced. Theoretically it should consume only about four and one-half horse-power per hour to effect the reduction, and in a new form of compound furnace to be built at our Lockport works, and in which 1,000 horse-power will be consumed, it is confidently expected that the output of bronze will not consume more than fifteen to twenty horse-power per hour for the reduction of one pound of aluminum.

Economy of the Process.—This may best be judged by the public in a general way from the fact that we are selling our ten per cent. aluminum-bronze as low in some instances as forty-five cents per pound net, and we are not selling it at a loss financially. This same bronze cannot be purchased elsewhere for less than $1.30 per pound. Our list price on ten per cent. bronze is sixty cents per pound.

The two and one-half per cent., five per cent. and seven and one-half per cent. bronzes are all proportionately less in cost. By the addition of zinc to the lower grades of aluminum-bronze an aluminum-brass is produced which is at once tough and malleable and of at least three times the tensile strength of ordinary brass. This brass has also vastly superior power to resist corrosion and oxidization. It can be made from the aluminum-bronze at a total cost of eighteen or twenty cents per pound.

Value of Electric Smelting.—"The Cowles Electric Smelting and Aluminum Company" claims that its process of electric smelting, within the next five or ten years, is destined to as completely revolutionize the brass and bronze trade of the world as the Bessemer converter has the iron and steel industry. This claim is based simply upon the ease and cheapness by which it can produce the alloys of aluminum and silicon, and the vast superiority of these alloys over any composition now in the market. It is further believed that cheap aluminum-bronze means a new era in warfare; that it insures a return to the age of bronze in the matter of heavy cannon, armor plates, gun carriages and small firearms. Why aluminum-bronze is the best metal for heavy guns is because sound, reliable and malleable castings can be made

of at least fifty tons tensile strength per square inch, an endurance that far exceeds that of any forged iron or steel when made into heavy guns, and a finished gun of this kind can probably be manufactured in one-quarter of the time and at far less the cost of one made of steel. Heavy pieces of steel ordnance now cost from seventy-five cents to $1 per pound, require a vast plant for their production and a very long time for completion. The same guns made from aluminum-bronze could be cast in an ordinary foundry of sufficient capacity and finished in a lathe, thus avoiding all forging, welding, shrinking on of rings, tempering, drilling and annealing now required in the manipulation of heavy steel and iron cannons. Armor plates for heavy fortifications and ships could be made completely from cast metal, no machine work being required to finish them ready to go into place.

For cartridges, we believe that sheet aluminum-bronze will prove to be unrivalled by any composition now known, for it is the only cheap metal not affected chemically by gunpowder, and that in turn does not deteriorate the gunpowder when stored for a period of years. It is so strong, and so much less in specific gravity than brass or copper, that the cartridge shell may be made of one-half the weight now required. Aluminum-bronze is likewise most admirably adapted, on account of its enormous tenacity and stiffness and resistance to all forms of corrosion, for torpedo boat cylinders and steam boilers, seamless tubes, stay bolts, and particularly rivets, where great strength is required and there is any tendency to shear off the heads, for it is as easy to obtain fifty tons tensile strength in an aluminum-bronze rivet as it is twenty-five tons in iron.

The Future of the Process is one of great promise, and will undoubtedly lead to the production of cheap and pure aluminum itself within a very brief period.* Indeed, "The Cowles Electric Smelting Company" asserts, on the back page of its pamphlet, that it expects to put the pure metal on the market within a year. When you are informed that we can charge iron, manganese, tin, copper, nickel, etc., with a very high percentage of metallic aluminum in this furnace, and that, also, without any base metal in the furnace, we can saturate the charcoal contained therein with metallic aluminum, most of which will be in a state of mechanical

* See Note at end.

mixture with the carbon; and further, that we have produced specimens of aluminum ninety-nine per cent. pure in at least three different methods by the electric furnace; and that notwithstanding all this we have not made much of an effort in this direction, the majority of you will agree that the great problem of producing pure and cheap aluminum is practically solved. How cheap this method will be you may judge from the fact that, at our Lockport works, which will have a capacity of only two or three tons per day, we expect to produce the aluminum in bronze with the little silicon contained in it at a cost not to exceed forty cents per pound, or with copper at twelve cents per pound, the bronze will really cost but about fifteen cents per pound.

In truth, "The Cowles Electric Smelting and Aluminum Company" is founded upon the faith that ere long we shall be marketing pure aluminum at a cost not exceeding fifty or sixty cents per pound. An appreciation of how cheap this would be, can be had from the fact that one pound of aluminum would go about as far as three and one-half of copper, it being that much more bulky, and in reality it would be about as cheap as copper at eighteen cents per pound, without counting its vast superiority over copper for many purposes on account of its greater lightness and resistance to corrosive influence.

Thanking you, gentlemen, for your attention, I would respectfully call your attention to a collection of ore, carbon, white bronze, furnace products, specimens of sheet and wire, and other manufactures of aluminum-bronze, that I have brought with me for your inspection.

[NOTE.—Since the above paper was filed with the Secretary of the Institute, it was found possible to prolong the length of the "heats" of the furnace to five hours, and increase the charges to over 100 pounds in weight, and during the same week a button of cast aluminum, five ounces in weight, was separated from the matrix of carbon, in which it was reduced by a process so simple and economical, that the production of pure aluminum from its oxide by the agency of heat and carbon only, is now demonstrated beyond all question.—E. H. C.]

DISCUSSION.

MR. THOMAS SHAW.—"What do you estimate to be the cost of operating with water-power, as compared with steam-power?"

MR. COWLES.—"Water-power is certainly the cheaper, where it can be had at first cost."

MR. A. E. OUTERBRIDGE, JR.—"Have you any idea, approximately, of the temperature developed in your furnace?"

MR. COWLES.—"We have no opinion on this point, further than that the temperature is probably as high, or higher, in spots, than that of the arc, because of the fact that the heat is prevented from being wasted or dissipated, owing to the heat-retaining character of the surrounding walls."

MR. OUTERBRIDGE.—"Does the metal flow away after reduction?"

MR. COWLES.—"No; the capillary action of the pulverized charcoal prevented this from taking place, just as fine flour or dust sustains drops of water and prevents them from flowing away."

MR. SHAW.—"How often is it necessary to renew the linings of your furnaces?"

MR. COWLES.—"About once a week."

PROF. W. H. GREENE.—"Have you succeeded in reducing metallic calcium from its oxide?"

MR. COWLES.—"Professor Mabery has reported that we have done so, and Professor T. Sterry Hunt, who spent some time with us in Cleveland observing the action of our furnace, witnessed the run or heat in which the reduction was made. We have also reduced metallic boron from boracic acid, and silicon from silicic acid."

DR. GOLDSCHMIDT.—"I saw at the meeting of the American Association for the Advancement of Science, two forms of silicon, one consisting of black crystalline particles, and the other greenish in color. What is the difference between them?"

MR. COWLES.—"The greenish material we believe to be partially reduced silicon, or a new sub-oxide of silicon, not hitherto observed. Our reasons for this are that it is always found at an intermediate position, between the completely reduced silicon at the top and the fused silica at the bottom."

MR. OUTERBRIDGE.—"Do you observe any relation between the percentage of silicon in your alloys and their ductility?"

MR. COWLES.—"We believe that the small percentage of silicon obtained in the alloys is a benefit to them, by increasing their tensile strength. This is effected by the metallic silicon absorbing

any oxygen taken up by the metal in the process of casting, and rising to the surface as silica, thus freeing the metal from such impurity. This is proven by the fact that on European aluminum-bronzes, thus far made, have exhibited as high a tensile strength as our bronzes, by as much as twenty per cent. The highest test of an aluminum-bronze casting other than ours, that we know of, is 94,000 pounds per square inch, while a casting of ours, which was tested some two weeks ago at the Washington Navy Yard, by Lieut. Hall, exhibited a tenacity of over 114,000 pounds per square inch, and we can, and frequently do, make to order, metal of 100,000 tensile strength in castings, while 90,000 pounds tensile strength is our ordinary standard for ten per cent. bronze; in other words, we let none go out of our works having less than 90,000 strength."

MR. ——— —"Why does not the molten metal short-circuit the furnace?"

MR. COWLES.—"One reason for that probably is, that as the metal becomes highly heated its conductivity is greatly diminished; another, possibly, is that the formation of an alloy, such as aluminum-bronze, may still further decrease its conductivity, since it is well known that alloys are often higher in resistance than their constituent metals; but above all, the great preventive would be the volatilization of the metal as soon as any considerable portion of the current started through it, which would cause a boiling of the mass and thus break up any contacts that should be made between the electrodes. At least, whatever may be the true reason, we find that we have had little or no trouble from this cause during the year that we have been in operation."

THE SECRETARY.—"A few comments, Mr. President, on the general bearings of this important subject may not be out of place here, for the benefit of those who may not be familiar with its technical features. The late Sir William Siemens, I believe, was the first to suggest the utilization of the intense heating effect of the voltaic arc for metallurgical purposes. He carried this suggestion into practical effect, also, by constructing what he termed an 'Electric Furnace,' and at the Southampton meeting of the British Association, in 1878, he described a series of experiments which he had made with this furnace in melting steel, nickel, platinum and other refractory metals, which demonstrated the enormous heating effects attainable by this means.

"It is worthy of note, however, that nowhere in this paper does it appear that he had conceived the idea of using his furnace to effect chemical operations such as the reduction of refractory ores. That this should have escaped the notice of an intellect so keen, and so thoroughly practical in its bent, is quite remarkable. It remained for the Cowles brothers to take this step in advance. They conceived the idea of a metallurgical furnace in which the reducing action of carbon should be greatly reinforced and exalted by the enormous heat of the electric arc. The results which they have succeeded in obtaining, Mr. Cowles has set forth in his most interesting paper, and are visible in the instructive array of specimens which he exhibits before you.

"In view of what has been accomplished so early in the history of this invention, it is risking nothing to predict that when its capabilities shall have been fully developed, it must prove of great advantage to the metallurgical arts. Already, it is almost as good as assured, that it has solved the difficult problem of producing aluminum cheaply, so that we may expect soon to see it taking the leading position in the arts for which its remarkable qualities appear to fit it so eminently, and from which its high cost, as compared with copper, tin and other useful metals, has hitherto debarred it. The extraordinary reducing power of the electric furnace justifies the expectation also, that, with its aid, the world may soon be enriched by the gift of many alloys of unknown and remarkable qualities.

"The happy conception of the Cowles brothers has armed the metallurgist with a vastly more powerful weapon than he has hitherto commanded, with which he will be able to achieve results heretofore unattainable. I am sure you all join me in offering them the hearty congratulations of this Institute."

At the close of the discussion, the meeting passed a unanimous vote of thanks to Mr. Cowles for his able and interesting address.

A PYTHOGOREAN PYRAMID.—G. Petrowitsh has communicated to the French Academy a trigonometric study of a pyramid, to which attention was called by M. L. Hugo, and which has for its base a right-angled triangle. The sides of the base being respectively in the ratios of the numbers 3, 4, 5, the faces of the pyramid satisfy the equation $3^3 + 4^3 + 5^3 = 6^3$, the number 6 being the area of the base.—*Comptes Rendus, Sept. 14, 1885.*

A NEW APPLICATION OF THE PRINCIPLE OF COMPOSITE PHOTOGRAPHY TO THE IDENTIFICATION OF HANDWRITING.

Francis Galton was the first to point out in fugitive memoirs, and notably in his epoch-making work, "The Human Faculty," that one could sift the common from the accidental features of a number of objects by exposing them to a sensitized plate in such a manner that the similar parts of the different objects should occupy as nearly as possible the same part of the plate, and that each object should be exposed for only a fraction of the length of time necessary to complete a picture on the film used. This fraction depended generally, if not always, on the number of objects and on the sensitiveness of the film. For example, if there were eighteen objects and the plate took thirty-six seconds to develop, each object would ordinarily be exposed for two seconds. It is easy to see that the result in the finished picture would be that those features which all the objects had in common would be re-enforced by each separate exposure, whereas those features which were accidental or variable, and which would be different for every individual, would be exposed for but two seconds and would be so indistinct as practically to fade away. Where the object was to catch a family likeness by exposing all the members male and female to the same portion of the plate, the result is a curious medley of faint whiskers, and moustache; of hair parted in the middle and at the side; of female gowns with buttons to the throat and of male shooting jackets thrown open. But out of all this faint halo of confusion and blur, there starts a characteristic face which is the family type. Very often, too, this type face resembles noticeably two different members of a family between whom no one can find a resemblance. It is this latter fact (which might have been expected) that induced me to look to the process for aid in resolving the difficult problem of identity of origin in handwriting. When a number of animals of the same race are thus treated, the method secures the fixing of the race or family characteristics, etc., as the case may be. When a number of pictures or coins bearing different representations of the same individual or scene are the objects, the result is to obtain either the average appearance of the same thing under different conditions (as for instance a man at different times of

life), or the average of the impression made by identically the same thing on different artists. In this case, the merit of the process is that it constructs its image out of all that many pairs of trained eyes have seen, without giving undue weight to any one pair. So far then, these efforts have been directed to re-finding a lost or concealed existence through multiple testimony, very much as the law tries to get at the truth by examining a number of witnesses.

The case of handwriting is, however, a different one. With a given mental image before one of what one desires to write; and with a given relation of will-power, nerve sensitiveness and muscular force, the same signature could be repeated a thousand times, provided that all these conditions were invariable, and no others were superadded. So far from this being the case, however, every one of the factors just named, which produce a signature depends on physical and mental—in other words, on extraneous influences, to a very large degree. A desire to make an up stroke, and the movement commenced to effect this, is met by an unexpected obstacle in the paper, a slight twinge in the shoulder, or a sudden noise, and the projected line would show (were we sufficiently cognizant of the detailed working of all the complicated parts of our mental machinery) just the order in which the different sentient and executive parts of us had been affected, and to what extent. But while these ever-recurring accidents result in preventing the signature from ever being made exactly as intended,* the fact that no two of them effect the same kind or amount of deviation leaves it in the power of the experimenter to extract from this process the "ideal" signature—a signature which probably never was seen as it appears, and yet which so combines all the visible results of a particular will acting on a particular arm to trace a known design with a pen or pencil on paper, that it may justly be called the *type* signature of that writer. What was said of the resemblance of every object of a group to the composite made of that group (provided the objects chosen have any claim to be so associated), while often differing widely from other members of the same group, is true of handwriting. It has been remarked that the composite signature is an ideal, and never was realized. This is because the lines along which the strongest

* The word "intended" is used to imply the effect of the will through the hand if not modified by these accidents, and not conscious intention.

reënforcement is made are those where locally varying deviations most frequently cross. To put it in another form, suppose the lines a, b, c and d to be in agreement as follows: At the point a', b does not cross, but c and d do. At b', c does not cross, but d and a do. At c', d does not cross, but a and b do. The line which, without very minute inspection, would represent to the eye part of the ideal signature, would be that traced through the points a', b', c', d', because those points having superposed lines of three out of the four signatures would be darker, while the variations at each of these points would be indistinct.

In examining with care a composite signature as just described, it at once arrests the attention that the variations are not equally distributed over the entire body of the letter, but that there are regions of each letter where variation of a particular kind is noticeable, and other regions where there is little or none. The more writings of an individual are compared the more forcibly does this fact appear, until finally one is tempted to conclude that after a handwriting is once formed, it cannot *naturally* exhibit deviations except within a defined variation and in certain limited areas adjacent to the separate letters. It is thus as great an assistance to the observer to study the variations as to study the ideal signature. Indeed, the variations are all important in the matter of identification, and if there were no variations the method would be inapplicable. A comparatively small number of signatures will give the maximum and minimum of variation in any given region of one of the letters forming it. Moreover, the kind of variation is easily observed where there are a number together, so that the most perfect adept at forgery could hardly hope to simulate the microscopically minute characteristics of variations which are simply the visible expression of a series of indefinitely complex relations of muscle and nerve.

In a case which was recently brought before the Orphans' Court in this city, this principle of composite photography was for the first time applied by me to the purpose of identifying handwriting, and from the experience thus far gained, it is thought that it will better accomplish the object than will the mere opinions of the most experienced experts.

PERSIFOR FRAZER.

Philadelphia, January 19, 1886.

THE LAW OF CONDENSATION AND EXPANSION OF STEAM IN SINGLE AND COMPOUNDED CYLINDERS.

BY WILLIAM DENNIS MARKS,
Whitney Professor of Dynamical Engineering, University of Pennsylvania.

In this JOURNAL for August, 1880, the writer published a paper, ("The Limitations of the Steam Engine,") showing that condensation being neglected, the economy of steam used per horse-power per hour varied as the logarithm of the boiler pressure of the steam divided by the back pressure.

This it is true was only an approximation of a rude nature, but it showed conclusively the limitation of economy of expansion due to *Marriotte's Law* under such conditions as would appear most favorable to expansion of steam without condensation.

It further showed the slow increase of economy due to the law of logarithms, and would seem to limit expansions to ten or twelve volumes without further condition than that of restraining the size of a cylinder within reasonable limits for any given power.

The writer then remarked "both Watt and Oliver Evans were partially right in their attempts to increase the economy of the steam engine. Watt was right in perfecting more and more the vacuum obtained, and Evans in increasing the steam pressure at the boiler.

"Neither of them were wholly astray, but were soon met and their progress stopped by the slow increase of economy beyond certain limits, and by the practical difficulties arising from surface condensation in the pursuit of a partially apprehended law.

"It is evident that we are limited as to the steam pressure, and that a great increase or a great decrease of the back pressure by reason of the more perfect vacuums will render the point of cut-off so early, the mean effective pressure so low, *and the condensation so great*, that the necessary increase in the volume of the cylinder will prevent that compactness and concentration of power so desirable in the steam engine, and although it has already been shown that high rotative speed aids in rendering the engine compact we are also limited in that direction."

At the time of that writing the writer was not aware of any exact experimental work which was of such a systematic character as to lead to the statement of the law of condensation of steam in a utilizable form.

As a fact, probably Watt and a long line of followers knew that great expansions meant greater proportional losses through condensation.

I take the following paragraphs regarding Watt's work from "Galloway's History of the Steam Engine," page 30 (edition of 1828).

"But in the year 1763–64, having occasion to repair a model of Newcomen's engine belonging to the Natural Philosophy Class of the University, his mind was again directed to the subject. At this period his knowledge was principally derived from Desaguliers, and partly from Belidor. He set about repairing the model *as a mere mechanician*, and when that was done and set to work, he was surprised that its boiler was not supplied with steam, though apparently quite large enough (the cylinder of the model being two inches in diameter and six inches stroke and the boiler about nine inches in diameter); by blowing the fire, it was made to take a few strokes, but required an enormous quantity of injection water, though it was very lightly loaded by the column of water in the pump. It soon occurred to him that this was caused by the little cylinder exposing a greater surface to condense the steam than the cylinders of larger engines did in proportion to their respective contents, and it was found that by shortening the column of water, the boiler could supply the cylinder with steam and the engine would work regularly with a moderate quantity of injection. It now appeared that the cylinders being of brass would conduct heat much better than the cast iron cylinders of larger engines (which were generally lined with a strong crust), and that considerable advantage could be gained by making the cylinders of some substance that would receive and give out heat the slowest. A small cylinder of six inches diameter and twelve inches stroke was constructed of wood previously soaked in linseed oil and baked to dryness. Some experiments were made with it, but it was found that cylinders of wood were not at all likely to prove durable, and that the steam which was condensed in filling it still exceeded the proportion of that which was required in engines of larger dimensions. It was also ascertained that unless the temperature of the cylinder

itself were reduced as low as that of the vacuum, it would produce vapor of a temperature sufficient to resist part of the pressure of the atmosphere.

"All attempts, therefore, to reduce, by a better exhaustion by throwing in a greater quantity of injection water, was a waste of steam, for the larger quantities of injection cooled the cylinder so much as to require quantities of steam to heat it again, out of proportion to the power gained by having made a more perfect vacuum."

Thus we see that Watt recognized the condensation due to the relative surface exposed, as also that due to the difference of temperature between exhaust and initial steam. With the rude machines then in use, it was out of the question for him to attempt to reduce the condensation by high rotative speeds.

In a lecture delivered at the Institute of Civil Engineers, May, 1883, Sir William Thomson used the following words: "In physical science, a first essential step in the direction of learning any subject is to find principles of numerical reckoning, and methods for practically measuring some quality connected with it. I often say when you can measure what you are speaking about, and express it in numbers, you know something about it, but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely in your thoughts advanced to the stage of science whatever the matter may be."

It was with the feeling so well expressed by Professor Thomson, that the writer undertook to find out, as well as he could, whether the Newtonian law of cooling was applicable to the action of steam inside the steam cylinder. In this JOURNAL, March, 1884, the attempt was made to follow the passage of steam through single and compounded cylinders in the following words, and to verify Newton's law of cooling in the case of steam:

"The order of events would seem to be as follows: The engine having attained its regular speed and the cylinder an average heat, the entering steam, touching the interior of the cylinder, condenses instantaneously, and warms it up to the temperature of the steam. This warmth proceeds to a depth proportional to the depth already cooled by the exhaust. The steam then expands after

cut-off, falling in temperature and losing heat, (1.) by warming up the cooled cylinder walls, (2.) in doing work. However, the heated iron of that part of the cylinder exposed before cut-off gives up heat and vaporizes the condensed water of initial condensation in the attempt to equalize the temperatures throughout the cylinder, which is effected by a transfer of condensation following the motion of the piston head. At the end of the stroke, the temperature of the whole internal *surface*, and of the steam, is that of the terminal pressure, the steam having really expanded with fresh accessions of heat and of vapor from that part of the cylinder exposed to initial steam that is exposed before the cut-off occurs.

"Next in the order of events, the exhaust opens, and the whole interior of the cylinder is exposed to the temperature of the exhaust, the piston and cylinder head being exposed on an average twice as long as the cylinder walls.

"In every engine, these changes whatever they may be, establish an equilibrium among themselves, and the result is that a certain uniform quantity of heat is lost each stroke, provided the thermal value of the steam does not vary."

Again, regarding compounded cylinders, the writer said:

"We have carefully followed the action of the steam while passing through one cylinder. Let us follow it through the two cylinders. The steam entering the non-condensing cylinder suffers initial condensation, in some instances quite copious, but not so great as if the non-condensing cylinder had the temperature of the exhaust, T_e; however, the cut-off being later than would occur with the same ultimate expansion, E, in a single cylinder, the initial condensation will be found to be very considerable.

"The steam being cut off in the non-condensing cylinder, re-evaporation begins, the expansion line being held closely to an equilateral hyperbola.

"This re-evaporation is, however, far from being complete, and at the end of the stroke communication is opened to the condensing cylinder. At this instant a relatively enormous initial condensation occurs, because of the great surface of condensing piston and cylinder head presented at the temperature of exhaust, but this condensation is met at once by the equally as active re-evaporation which simultaneously occurs from the whole interior

of the non-condensing cylinder, the result being the transferring of the condensation from the surface of the non-condensing cylinder to the surface of the condensing cylinder until the temperatures are equalized.

"After the violence of this first transfer of condensation has abated, the re-evaporation from the interior of both cylinders occurs with sufficient alacrity to hold the expansion curve closely to an equilateral hyperbola.

"If but two cylinders are used, the condensing cylinder is now opened to exhaust and the re-evaporated and vaporous steam enter the condenser, carrying much more heat than would appear from a calculation of the thermal value of the vaporous steam present at the end of expansion.

"Thus we see that at the present day the compound engine owes its possible greater efficiency to the physical attributes of iron rather than to the properties of steam, and that with the use of non-conducting materials, the necessity of compounding cylinders will vanish."

With a clear comprehension in a qualitative way of the phenomena of the condensation of steam, it might be possible to deduce a quantitative law which would serve for practical use, and which in combination with Marriotte's law would form a new law, serving to solve the problem of the most economical number of expansions for any type of engine.

The extreme limitations to expansion are at once placed by its logarithmic increase of economy; a law deduced by the writer from a combination of the Warrington-Thompson law for the expenditure of steam per horse-power per hour, and Marriotte's law of expansion without regard to condensation.

This logarithmic law of economy of steam receives a curious and practical verification at the hands of the builders of compound engines, who, as the result of many experiments never recorded, have fixed upon a ratio of one to three for non-condensing and condensing cylinders as the most economical for practical purposes.

In this JOURNAL for January and February, 1884, I say:

"It has been shown that the ratio of volume of the cylinders of a compound engine is a function of the ultimate expansion of the steam under the conditions that the power of the cylinders is equalized, and that no drop be permitted in the steam pressure during its course through the engine.

TABLE OF RATIOS OF CYLINDERS AND POINTS OF CUT-OFF IN NON-CONDENSING CYLINDER AND FOR ULTIMATE EXPANSIONS OF STEAM.

$$\text{Criterion } \frac{2\ R \log.\ R}{R-1} = \log.\ 2{\cdot}7183\ E$$

$$e = \frac{R}{E}.$$

Ratio of Cylinder Volumes.	Ultimate expansion of Steam.	Point of Cut-off in Non-Condensing Cylinder.
R	E	e
1¼	3·426	0·37
1½	4·190	0·35
1¾	5·015	0·34
2	5·886	0·34
2¼	6·813	0·33
2½	7·801	0·32
2¾	8·840	0·31
3	9·933	0·30
3¼	10·961	0·30
3½	12·277	0·28
3¾	13·580	0·28
4	14·832	0·27

REMARKS.

These computations are made for general guidance only, nearly all the assumptions made being impossible of exact realization.

It is assumed that a perfect gas is used expanding isothermally, that there is no back pressure on the condensing cylinder piston, and that there are no clearances or receiver, and further that there is no cut-off at all for the condensing cylinder, that only being demanded to provide for receivers and clearances in actual practice, and that the cranks are together, or 180° apart.

"It is useless to carry this table farther. Enough has been done to show the error of exaggeration of ratio, into which designers have fallen, when it is necessary to equalize the power of cylinders and to avoid an intermediate drop for the sake of economy.

"Indeed, in all engines it will be found that economy of steam as well as smoothness of action, demand that no sudden changes of pressure shall be permitted, and therefore it will be found advantageous in single cylinder engines where clearance cannot be indefinitely reduced to use enough compression to bring the back pressure up to the initial pressure, and so as not to permit an *explosion* in the cylinder at the beginning of each stroke.

"Whenever, as is the case with condensing engines or small non-condensing engines, it is not practically possible to make the number of expansions equal to the boiler pressure divided by the back pressure, we still have the same impassable barrier to exceeding

ten or twelve expansions set by Marriotte's law regardless of condensation.

"It is not possible to avoid initial condensation, to construct an engine without clearance, or to obtain a perfect vacuum; but if, for the purpose of obtaining an extreme limit, we neglect these, the equation for weight of water per horse-power per hour (JOURNAL F. I., August, 1880,) becomes

$$W = \text{constant} \times \frac{1}{1 + \text{nat. log.} \frac{1}{e}}$$

"If in this we substitute successive values of e, we obtain the successive percentages of water used per horse-power per hour.

$$\text{For } e = 1 \text{ we have } \frac{1}{1 + \text{nat. log.} \frac{1}{e}} = 1{\cdot}00$$

$$\text{For } e = \tfrac{1}{4} \text{ we have } \frac{1}{1 + \text{nat. log.} \frac{1}{e}} = 0{\cdot}42$$

$$\text{For } e = \tfrac{1}{8} \text{ we have } \frac{1}{1 + \text{nat. log.} \frac{1}{e}} = 0{\cdot}32$$

$$\text{For } e = \tfrac{1}{9} \text{ we have } \frac{1}{1 + \text{nat. log.} \frac{1}{e}} = 0{\cdot}31$$

"The gain by increasing the expansion from eight to nine times is but a theoretical one per cent. at the outside, and possibly there is an actual loss in the case of small cylinders or slow piston speed." —JOUR. FRANKLIN INST., Dec., 1883.

It is necessary thus to set bounds to the extremes between which it is worth our while to consider the effect of initial condensation in the steam cylinder.

We see that in the case of large engines or compounded cylinders there may be a gain in exceeding ten expansions, but it is necessarily a very small one if it exist at all, and may not be worth having, in the long run, even in compound engines.

There is another point which the reader should bear in mind: the curve of expansion of steam, in the best engines made, coin-

cides, with as great accuracy as could be wished for, with the equilateral hyperbola, and it is nonsense to discuss the curve of adiabatic expansion for engines until we have an adiabatic engine produced. Further, as long as we know the equilateral hyperbola to be an average of the curves produced by good indicators on good engines, the condensation of the steam during expansion, or its re-evaporation—in fact, its behavior during expansion, is of minor importance.

The first step in the quantitative investigation of the problem of the initial condensation of steam is the establishment of a standard, and the writer chose to make it: *The weight of steam condensed by a plate of cast iron one foot square when raised one degree Fahrenheit in one minute.*

Of course, it would be more accurate to say, the heat units absorbed, in the place of the weight of steam condensed, but that was at that time quite accurate enough for his purposes, which were and are purely practical, in the sense of desiring to take cognizance of the real facts in proportion to their importance only, and of wishing to avoid an attempt to reach greater accuracy in results than his premises would warrant.

The writer was exceptionally fortunate in basing his first investigation upon the thorough and skilful work of Mr. John W. Hill, upon so perfect an engine as the Harris-Corliss, in the competitive tests at Cincinnati, 1880.

Mr. Hill's conscientiousness led him to frankly say that he could not indorse his calorimetric work, and the careful use of two calorimeters in each case, in the boiler tests of the Electrical Exhibition of 1884, at Philadelphia, proved the unreliability of calorimetric work, and of the present forms of calorimeters.

On the other hand, in making Mr. Hill's work our basis, we are sure of an engine whose piston was tight working under the most favorable conditions of good practice, and, therefore, of obtaining a value of the constant of condensation not grossly in error.

A careful copying of Mr. Hill's methods of recording his work would have added very much to the value of the more recent experiments of Messrs. Gately and Kletzsch, which, nevertheless, are of great value, as throwing light upon some unexplored fields.

The clearance should have been determined. Diagrams should

have been published in conjunction with the record, and the amount of compression should have been carefully noted, as it doubtless has an important effect upon the condensation of the initial steam.

The acknowledged errors of their work gives honorable proof of their sincerity and scientific spirit. Indeed, a long and searching examination of quite a number of reputed scientific experiments upon the steam engine, leads us to believe this characteristic much rarer than is generally supposed, if we have not misunderstood the internal evidence of the records.

In this JOURNAL for March, 1884, "Initial Condensation of Steam Cylinders," we stated the following formula for the ratio of the actual steam from the boiler to the steam indicated at the point of cut-off:

$$r = 1 + \frac{S\,[T_b - T_e]}{62\frac{1}{2}\,N}\; C\left[\frac{4}{d} + \frac{2}{e\,s}\right] \qquad (8)$$

in which r = ratio of actual to indicated steam at cut-off.
S = specific volume of steam at cut-off pressure.
T_b = temperature of steam at cut-off. (Fahr.)
T_e = temperature of steam during exhaust. (Fahr.)
N = number of strokes per minute.
d = the diameter of steam cylinder in feet.
s = the stroke of steam cylinder in feet.
e = the fraction of the stroke at which steam is cut-off.
C = the condensation in pounds per minute of one square foot raised 1° Fahr.

This formula assumes that the interior of the cylinder already let down in temperature by a low terminal pressure loses heat to a depth proportional to the time of exhaust $\frac{1}{N}$ minutes, and four expansions approximately.

As already stated the cylinder and piston head have on an average twice as long an exposure to exhaust as the circular barrel of the cylinder.

It is to this value of C, the constant of condensation, that we must look to solve the vexed and much disputed question of the utility of steam jackets versus clothing of non-conducting materials. The following table, with the exception of Mr. Hill's experiments, has been computed for me by Assistant Engineer G. H. Bull, U. S. N.

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TABLE OF RESULTS OF EXPERIMENT AND CALCULATION OF CONDENSATION AND EXPANSION OF STEAM.

Experiments of J. W. Hill upon Harris-Corliss Engine, Cincinnati, 1880.

Number.	Stroke of Cylinder in Feet. s	Diameter of Cylinder in Feet. d	Fraction of Stroke Cut-off. Reciprocal of True Number of Expansions. e	Number of Strokes per Minute. N	Absolute Steam Pressure at Cut-off. Pounds. P_b	Absolute Steam Pressure during Exhaust. B	Temperature of Steam at Cut-off. Fahrenheit. T_b	Temperature of Steam during Exhaust. Fahrenheit. T_e	Specific Volume of Steam at Cut off. S	Ratio of Actual to Indicated Steam at Cut-off. r	Condensation Constant. C	Averages.	
(1.)	4·08	1·5	·1355	151·66	101·67		328 8	145·4	264·	1·657	·01868		Condensing. 10 hours' test.
(2.)	4·08	1·5	·1491	151·62	100·61		328	212 6	266·5	1·559	·02642		Non-condensing. 10 hours' test.

Experiments of Gately and Kletzsch. Harris-Corliss Engine. Sandy Hook, 1884.

CASE I.—Variable Cut-off Only. Condensing.

(3.)	3·5	1·5	**·589**	136·52	61·54	4·22	294·2	155·2	430·	1·294	·011554		
(4.)	3·5	1·5	**·443**	135·9	68·34	3·91	301·14	152·15	390·13	1·371	·013717		
(5.)	3·5	1·5	**·330**	134·64	62·10	4·48	294·80	157 56	426 35	1·512	·016704		
(6.)	3·5	1·5	**·131**	137·9	49·11	3·65	279 84	149·44	530·9	2·003	·017762		
											·059737	·014934	

CASE II.—Variable Steam Pressures Only. Condensing.

(7.)	3·5	1·5	·208	138·03	**78·80**	3·24	311 02	144·58	342·2	1·544	·015225		
(8.)	3·5	1·5	·206	141·44	**66·89**	3·83	299·69	151·88	398 1	1·917	im-possible		·025331 = C.
(9.)	3·5	1·5	·244	143·46	**53·21**	3·24	284·95	144·58	492·1	1 583	·013564		
(10.)	3·5	1·5	·210	137 82	**39·83**	3·61	266·74	149·02	642·9	1·707	·014952		
(11.)	3·5	1·5	·242	135·85	**26·74**	3·46	244·26	147·21	936·6	1·700	·013013		
		Average	226								·056754	·014188	

CASE III.—Variable Steam Pressures Only. Non-condensing.

(12.)	3·5	1·5	·412	135·96	**65·36**	14·70	298·16	212·	407·5	1·122	·007267		
(13.)	3·5	1·5	·420	137·14	**50·42**	14·82	281·30	212·4	504·5	1·307	·018810		
(14.)	3·5	1·5	·401	135 02	**40·52**	14·88	267·87	212·6	620·8	1·190	·011390		
(15.)	3·5	1·5	·466	133 04	**28·40**	14·84	247·56	212·49	886·6	1·376	im-possible		C = ·032721.
		Average	425								·037467	·0·2489	

CASE IV.—Variable Number of Strokes. Condensing.

(16.)	3·5	1·5	·938	**125·95**	27·38	3·15	245·56	146·31	916·2	1·322	·008515		
(17.)	3·5	1·5	·961	**100·6**	28·35	3·86	247·46	151·57	886·8	1·403	·009150		
(18.)	3·5	1 5	981	**67·48**	28·53	4·96	247 81	161 94	881·6	1·504	·008640		
		Average	·960								·026305	·008768	

From the more reliable figures of the two calorimetric results, given by Hill, it was found that the steam was super-heated about 200° Fahr., and in the paper of March, 1884, the assumption was made that the temperature of the steam was 532°, as also of the interior of the cylinder. In this table, the assumption is made that the temperature at cut-off is 328° that of saturated steam at the pressure of cut-off, and the weight of steam C is further corrected for superheating. The correction shown, formula (9) *et seq.*, has not been made and would give the correct value of C, much less, than the apparent one of the table. (*See Table.*)

The first method gives the more concordant results with a much less apparent value, in the case of Hill's experiments.

If we take account of the variable time of exposure of the cylindrical walls of the cylinder, as also of the variable value of the area of the cylindrical elements, we have for the time of exposure to exhaust, multiplied by the area,

For the piston head and the cylinder head.

$$\frac{\pi\, d^2}{2\, N}$$

For the variable area for each increment of the angle x, the crank being assumed to have a uniform rotary motion,

$$(\pi\, d)\, d\, s = + (\pi\, d) \frac{s}{2} \sin x\, d\, x$$

For the variable time $\frac{x}{180\ N}$ of exposure to exhaust of each element $(\pi\, d)\, d\, s$. For their product

$$\frac{\pi\, d\, s}{2\, N} \frac{x}{180} \sin x\, d\, x$$

For the product of interior of cylinder, between limits,

$$\frac{\pi\, d}{2\, N} \left[d + \frac{s}{180} \int_{x = \cos^{-1}(2\,e\,-\,1)}^{x = 180^\circ} x \sin x\, d\, x \right]$$

but, $\int x \sin x\, d\, x = \sin x - x \cos x$

for $x = 180°$ we have π

for $x = \cos^{-1}(2\,e - 1)$, we have $\sqrt{1 - (2\,e - 1)^2}\,(2\,e - 1) \cos^{-1} (2\,e - 1)$

Therefore we have, as a final quantity for any cut-off e,

$$\frac{\pi d}{2N}\left[d + \frac{s}{\pi}\{\pi - \sqrt{1-(2e-1)^2} + (2e-1)\cos^{-1}(2e-1)\}\right] \quad (9)$$

This latter expression should be multiplied by $(T_b - T_e)$ and placed within the square parenthesis of Formula 7, JOURNAL OF THE FRANKLIN INSTITUTE, March, 1884, should more exact results be demanded than are given by Formula 8, of same paper.

The last expression deduced will make considerable difference in the apparent condensation C per degree Fahrenheit of a square foot of iron in one minute, when we consider very early or late cut-offs, but as this is rarely the case where economy is desired, it is not of very great importance except in special cases.

Taking a value of $e = \frac{1}{4}$, we have from the previous expression

$$\frac{\pi d}{2N}(d + 0{\cdot}4\ s) \text{ very nearly.}$$

If we substitute the same value $e = \frac{1}{4}$ in Formula 7 we have

$$\frac{\pi d}{2N}(d + 0{\cdot}5\ s) = \frac{\pi d}{2N}(1{\cdot}5 + 1{\cdot}75) = (\ )\ 3{\cdot}25 \quad (10)$$

We see that it is hardly worth while to put ourselves to the trouble of the more complicated and correct formula as we rarely cut off later than $\frac{1}{4}$ in good engines of any size, and do not exceed that save in large engines, where careful work must always be done.

The average cut-off of Case III, Gately and Kletzsch experiments is $e = {\cdot}425$ and the condensation $C = {\cdot}012489$.

Substituting this value of e in expression (9), we have

$$\frac{\pi d}{2N}(d + {\cdot}656\ s) = \frac{\pi d}{2N}(1{\cdot}5 + 2{\cdot}296) = (\ )\ 3{\cdot}80 \quad (11)$$

Dividing the condensation ·0125 by 3·25, and multiplying by 3·80, we have ·0146 for the corrected value.

In Case IV, of the same experiments, $e = {\cdot}96$ and $C = {\cdot}0088$, we have from expression 9,

$$\frac{\pi d}{2N}(d + {\cdot}991\ s) = \frac{\pi d}{2N}(1{\cdot}5 + 3{\cdot}468) = (\ )\ 4{\cdot}968$$

Dividing $C = {\cdot}0088$ by 3·25, and multiplying by 4·968, we obtain ·0145.

Showing with the greatest certainty which now can be obtained that the condensation is directly proportional to the area exposed and its time of exposure to exhaust steam.

Since these concordant experiments were made with and without condenser at varying speeds, ranging from sixty-seven to 143 strokes per minute, with pressure varying from twenty-seven to seventy-nine pounds per square inch at cut-off, and with cut-offs varying from 0·21 to 0·98 of the stroke, it would seem permissible to assume the law of initial condensation of steam to have been correctly stated in the paper of March, 1884, JOURNAL FRANKLIN INSTITUTE

At the time of that writing, the author could find but one record, of an engine proved tight, which *seemed* accurate, and, feeling the natural hesitancy of one on wholly new ground, made the following remarks:

"The writer presents himself to his readers, not in the attitude of one having authority, but merely as a patient student of the real facts of the action of steam inside of the steam cylinder.

"So far as he knows, no writer, from the time of Carnot to this present date, has essayed to include all the data which must affect the condensation of steam in one general formula applicable to all cases.

"The factors which must enter into such a formula will be seen to be too numerous to admit of the graphical treatment which, following the high authority of Rankine, quite a number of his followers have essayed, with varying degrees of approximation to correctness of result, and apparently quite oblivious to the fact that they are reasoning in a circle from empirical statement of experimental results, and that they are shut out completely from the hope of logically searching for the best attainable conditions in the use of steam.

"Should it prove that this discussion of initial condensation is a scaffolding for the walls and roof of a structure which will house all the warring experimental proofs and mathematical discussions as to economy of steam, and that the hitherto unknown law of condensation of steam inside of the cylinder of a steam engine, has been formulated with practical accuracy; the writer will regard himself as most fortunate, in having been able to complete the actual theory of the steam engine at work.

"To the skilled mathematician and physicist, the use of thermal units in the place of weight of steam will give more exact results, *when we have sufficiently accurate premises to justify a reasonable belief that it is worth our while to use thermal units throughout.* At this point, too, we must not forget the condensation due to expansion, which has formed so favorite a theme for writers on thermodynamics.

"The use of the Metric system will also lighten the labors of one having a large amount of calculation to perform.

"In this departure from older paths, the writer cannot but feel that he is far from sure of his ground at all points, nor does he lay claim to infallibility, but presents his facts, computations and ideas for your your consideration and verification."

The writer now feels that he can justly lay claim to having established, by original methods of investigation, and with as great accuracy as can be reached in ordinary practice, the following laws of the action of steam in a steam cylinder.

The logarithmic law of economy of steam using, regardless of condensation, giving the extreme limitations of the expansion of steam—

(1.) When the number of expansions is equal to the boiler pressure, divided by the back pressure on piston.—JOURNAL FRANKLIN INSTITUTE, August, 1880.

(2.) When any number of expansions are used at will, with a given pressure.—JOUR. F. I., Dec., 1883, and Aug., 1880.

The law showing the ratio of the cylinders of a compound engine to be a function of the ultimate number of expansions under the condition of the most economical use of steam.—JOUR. F. I., Jan. and Feb. 1884.

The law of the initial condensation of steam in a steam cylinder.

The general laws of the economic expansion of steam under any conditions existing in steam cylinders, simple or compounded.

The establishment of a standard of condensation C, which will serve by proper experiment to determine the utility of steam jackets.—JOUR. F. I., March, 1884.

The inference from the general law of initial condensation that compression to boiler pressure reduces this condensation to a constant and a minimum under the assumption of four expansions. (approx.)—JOUR. F. I., June, 1884.

In addition to the experiments of Watt, we have a large number by D. K. Clark, G. A. Hirn and Chief Engineers Isherwood, Loring and Emery, all proving, under certain conditions, the overwhelming influence of initial condensation in the steam cylinder, but the writer is not aware that any of them has established a rational and general law, applicable in all cases where the piston and valves are proven tight

Philadelphia, January 18, 1886.

RAPID TRANSIT AND ELEVATED RAILROADS, WITH A DESCRIPTION OF THE MEIGS ELEVATED RAILWAY SYSTEM.*

BY FRANCIS E. GALLOUPE, M. E., BOSTON, MASS.

[*Continued from Volume CXXI, page 76.*]

Objects.—The Meigs elevated railway system is designed to meet the modern demand, and all the ordinary requirements of a railroad for the safe, quick and convenient transportation of passengers in cities, or to and from the suburbs of cities to such central points as passengers desire to go; while on longer lines, connecting cities and towns, to carry both passengers and freight, not only more economically and safely, but more speedily than has heretofore been done.

The New York structure is essentially an ordinary railroad, elevated, and is open to the criticisms of liability to derailment and consequent want of safety; a too great height of the position of the centre of gravity, and want of stability, by reason of the large leverage upon the posts when sustaining wind pressure upon the sides of the cars; and the well-known obstruction to light and air produced by the size of the structure in the street.

The fundamental principle of construction in the Meigs system is to *concentrate the strains due to the load upon the track directly upon the central line of the way*, avoiding all disadvantageous leverage. It is, in effect, to turn the ordinary track up edgewise, or vertically, with one rail lying directly over the other, instead of

*A paper read at the Boston meeting, 1884, of the Amer. Soc. Mechanical Engineers, and reprinted from advance sheets of the *Transactions*.

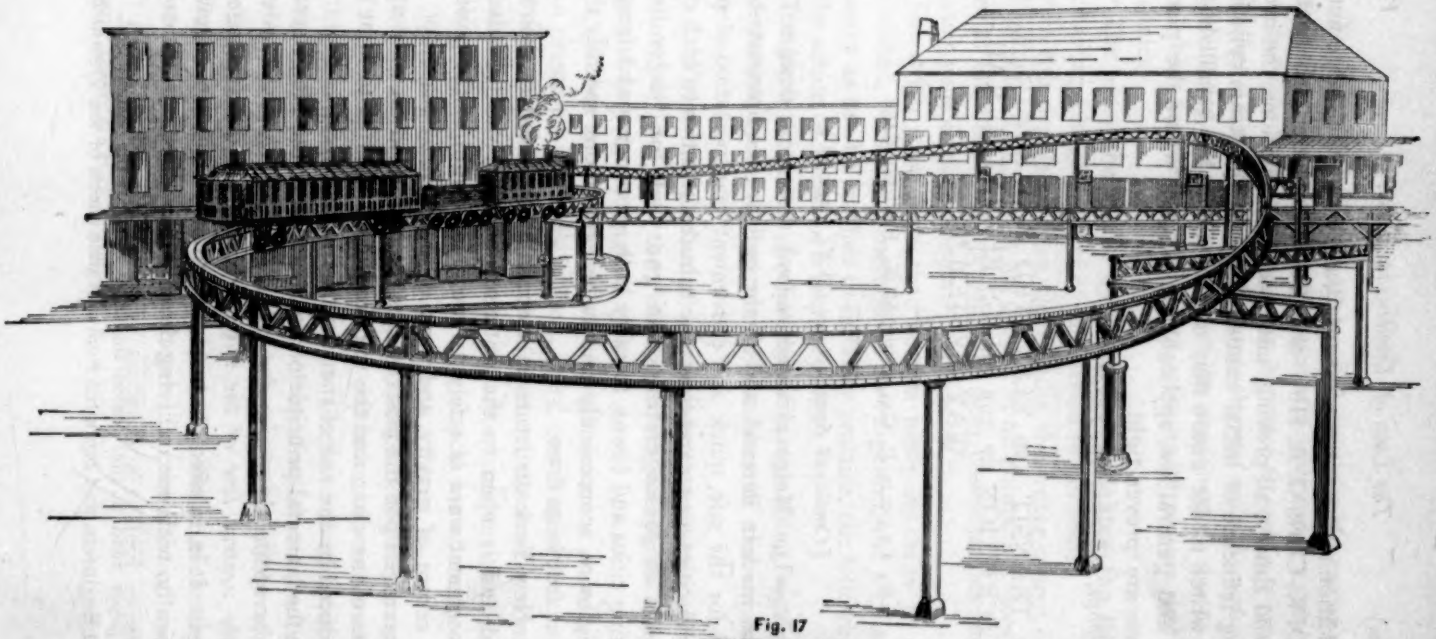


Fig. 17
GENERAL VIEW
Meigs's Elevated Railway.

side by side in a horizontal plane, as in all other railroads. Or, it is as though the Y of the posts in the New York system, as well as all the cross-ties, nine feet in length, were abandoned, and the double girder beneath the track condensed into a single central truss, removing four-fifths of the material causing obstruction to light and sight from the street.

Its general appearance is shown by *Fig. 17*.

In the execution of the design based upon these peculiar conditions, the roadway consists of a single lattice iron girder or truss, four feet in depth, and resting upon iron posts or columns placed 44·4 feet apart.

Distinguishing Features.—Its peculiar features and differences from the ordinary railroad exist in—

(1.) The Way;
(2.) The Switch;
(3.) The Trucks;
(4.) The Passenger Cars;
(5.) The Engine;
(6.) The Draw Bar; and
(7.) The Brakes;

as in the following description:

I. THE POSTS AND FOUNDATIONS.

The posts may be of wood, rough, hewed, or sawn square, for the wooden track system; or of iron when the iron way is used. In the latter case they will be of rectangular form, about 11 inches by 10 inches in section, and 24 feet in length. They are composed usually of two medium ten-inch channel bars, *f f*, *Fig. 22*, and two plates, *e e*, all about one-half inch in thickness, riveted upon and along the flanges of the channel bars and the edges of the plates. They thus form a hollow box-like structure, which may be varied in cross-section or thickness in special places, or may have the solid plates replaced by diagonal bars riveted in lattice form upon the channel bars. The weight of each post, having a sectional area of 23·8 square inches, is 1,919 pounds, the crushing load 235 tons, and safe load thirty-nine tons, while the greatest load that will be imposed on a post in any position of a passing train will not exceed thirty-five tons.

The foundations, as shown in *Fig. 18*, (this and all subsequent figures being in scale one-thirty-second of full size, or three-eighths

inch to the foot,) being a vertical section, and *Fig. 23* a horizontal section of one form, consists of a plate *c*, upon which the post rests, of somewhat larger area than the post, as shown in *Figs. 18* and *20*, or of a similar plate *c'*, as shown in *Fig. 19*, which has an upwardly presenting boss entering into its interior, set in and on a concrete foundation about 3 feet in diameter and 6 feet in depth. The

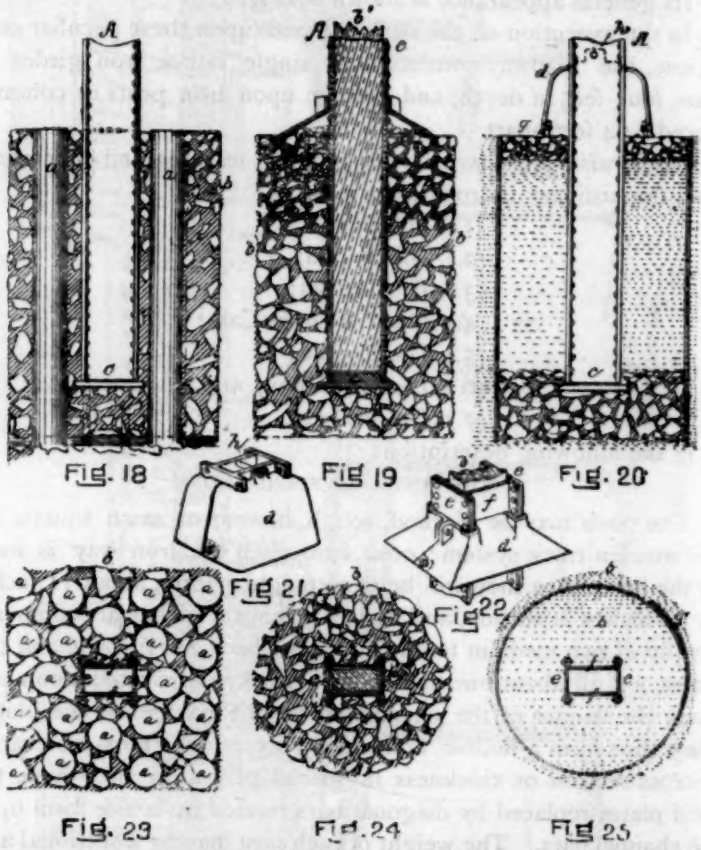


Fig. 18 Fig. 19 Fig. 20

Fig. 21 Fig. 22

Fig. 23 Fig. 24 Fig. 25

lower part of the posts may remain hollow, or they may be filled with concrete, *b'*, or with sand or other non-compressible filling, as shown in *Fig. 19*.

If the foundation is upon soft earth, the earth is packed, as shown in *Figs. 18* and *23*, by driving piles, marked *a*, all around the place where the post is to be set, and filling between, and over them, if necessary, with the concrete.

Where this is not necessary, another plan, shown in *Figs. 19* and *24*, is more usually followed, in which the post hole is simply filled with concrete and broken stone below.

Where the ground foundation is good, but the surface soil is mobile, as in the Mississippi valley and elsewhere, in which case side thrusts are not well resisted, still another method, shown in *Figs. 20* and *25*, may be employed, consisting of a stout resistant boxing or lining to the post hole, of iron or wood, as shown at *g*, and filled with concrete or sand inclosed between concrete ends, thus forming a strong side support to the post, practically increasing its section below the ground many times. At the surface of the ground the posts may, if advisable, be additionally braced or guarded from abrasion and injury by passing vehicles by means of caps or collars, *d* or *d'*, shown in *Figs. 21* and *22*. These are either of cast or wrought iron, made in two parts, and bolted together and to the post by means of ears or bolts passing through the post.

These posts, so set, at a distance of 44·4 feet apart, will be amply sufficient in strength to carry safely a girder capable of supporting substantially such trains as are now in general use, at a height of at least fourteen feet from the ground to the bottom of the girder.

II. THE WAY.

The way upon which the train runs, *Figs. 26* and *28*, consists, as before stated, of a single iron girder or truss for each span, four feet in depth, placed centrally over the line of posts, and comprises an upper track-beam, a lower track-beam, upon the sides of each of which are carried the rails, and between these track-beams the bracing or trussing. At the proper height for resting the lower track-beam the bracket angle-irons, *i*, are riveted upon each post, and on these irons the lower portion of the girder rests. The upper track-beam rests upon the extreme top of the posts, and through the diagonal braces supports the trucks and cars, whose weight is carried upon the lower track-beam.

The lower track-beam of the girder, *C*, is a box-beam, composed of two channel bars, *l l*, *Fig. 26*, to which are riveted flat plates, *k k*, which in turn are securely riveted to the post sides by angle-irons. In the exterior recesses formed by the channel bars are imbedded wooden beams, *m m*, one on either side of the line

of posts, which may be single sticks or composite beams made up of several pieces, and which act as rail stringers. Across the girder at intervals of about two feet are riveted T or double angle-irons, as shown at *n*, *Fig. 28*, in order to bring the entire strength of the iron into action.

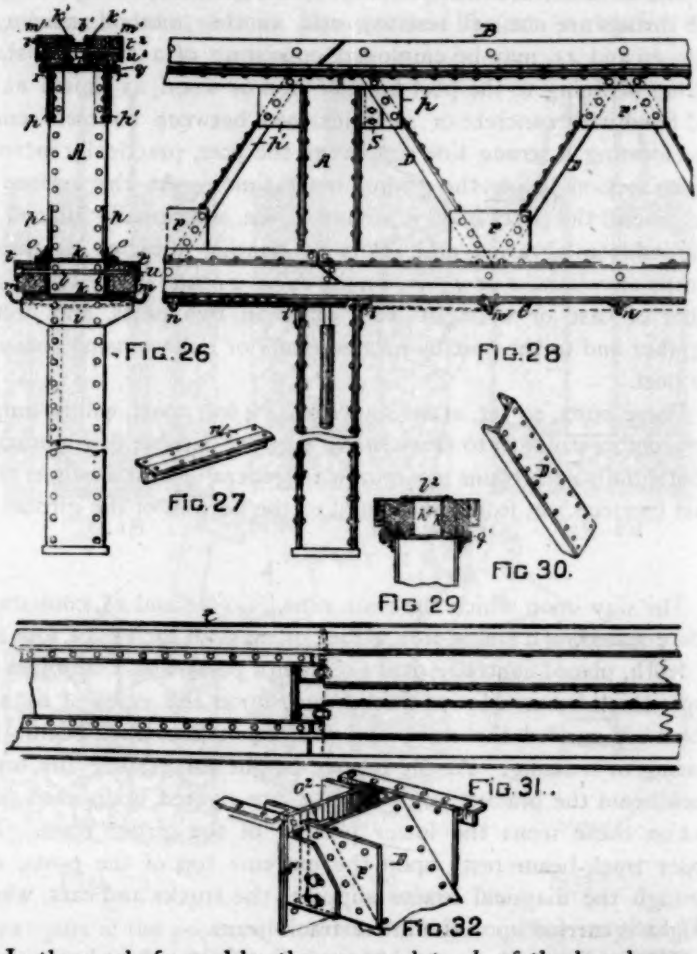


Fig. 26

Fig. 28

Fig. 27

Fig. 30.

Fig 29

Fig. 31.

Fig. 32

In the angle formed by the upper plate, *k*, of the box-beam, *C*, with the channel bars, *l*, on its outside, the angle-irons, *O*, are also riveted. These may be made much deeper than shown, so as considerably to stiffen the girder and serve as attachments for the braces, *D*; or, as shown, attachment plates, *p*, are inserted at the

proper intervals and riveted to the angle-irons, *O*, and diagonal braces, *D*, composed, as shown in *Fig. 30*, of two angle-irons and a plate, or of channel bars, or I beams, attached by similar plates to the upper track-beam.

The upper track-beam, *B*, of the girder, is also a box-beam, composed of two channel bars, $l' l'$, and two exterior angle-irons, $k' k'$, reinforced by angle-irons, $r r$, all well riveted together and carrying in the recess formed by the exterior angle-irons the stringer beams, $m' m'$, of solid or compound sticks of timber, for supporting the rails, as described.

An expansion joint, *Fig. 32*, is formed at the end of these upper track-beams, by means of a bracket, *S*, firmly riveted to the post, to which the brace portion, *D*, and the attachment plates, p', are fastened by bolts passing through slots of sufficient length to allow for the ordinary expansion or movement of each section of the way, due to changes of temperature.

The lower surface of the upper box-beam rests upon a terminal plate at the top of the post, which thus takes its weight, so that these brackets in the slip-joint serve only as guides. The upper beam may also be made up as shown in *Fig. 29*, in which g' is the lower plate connecting the two lateral channel bars of unequal flanges, $k^2 k^2$, and l^2 a top plate to form the box-beam. The purpose of using wood for the track stringers is not only to form a continuous support for the rails and a convenient substance for the attachment of the rail fastenings, but to assist in the preservation of the alignment of the way due to its freedom from expansion by heat, and also to aid the iron work in resisting longitudinal stresses upon the girder, as in braking a train. It also supplies required elasticity for rails and girder, saving the iron from unnecessary wear from knocking and pounding, in several important respects.

The rails of this structure are four in number; the two bearing rails, which carry the load of the car, being angle-irons placed upon the outer upper edge of the stringers, *m*, upon the lower track-beam. They are marked *t* in the figures, and are fastened to each other, to the stringer-beams, and to the lower track-beam of the girder by through-bolts, *u*, as shown. The upper track-beam also carries two vertically placed rails for the balancing or friction wheels, lettered $t^2 t^2$, and are similarly held to the stringers, which project over the line of posts and braces and have a small recess

beneath them under which flanges upon the horizontal wheels run to securely lock the truck upon the track.

The horizontal distance from outside to outside between the lower rails which is found to be sufficient for transverse stiffness is twenty-two and a-half inches, which thus constitutes the gauge of the road and the total width of the way with its rails in the street; the corresponding gauge of the upper rails being seventeen and one-half inches.

It is anticipated that the form of rail section in common use will be eventually adopted in permanent constructions, in which case the lower wooden stringers would be chamfered off at their upper outward corners to take the rails, whose axes would incline at an angle of about 45° with the vertical. The length of the posts, twenty-four feet being usually sufficient, occupying four feet for the truss and six below the surface of the ground, giving fourteen feet clear way beneath the truss, will be varied to follow the grades and contour of the ground; and at freight houses the girder may be sunk below the surface two feet, to facilitate unloading upon low platforms or into teams, or remain at grade, the platforms and road being raised the same amount.

The present cost of building the permanent way is about as follows:

		Per Mile.
Iron	Way, with high posts, ...	$70,000 to $75,000
"	" " low posts, ...	50,000 to 55,000
Wooden	" " angle-iron rails, ...	20,000 to 25,000
"	" " round posts and sawed wooden rails,*	6,500
"	" " hewed track-stringers and hard wood rails,*	4,500

III. THE SWITCH.

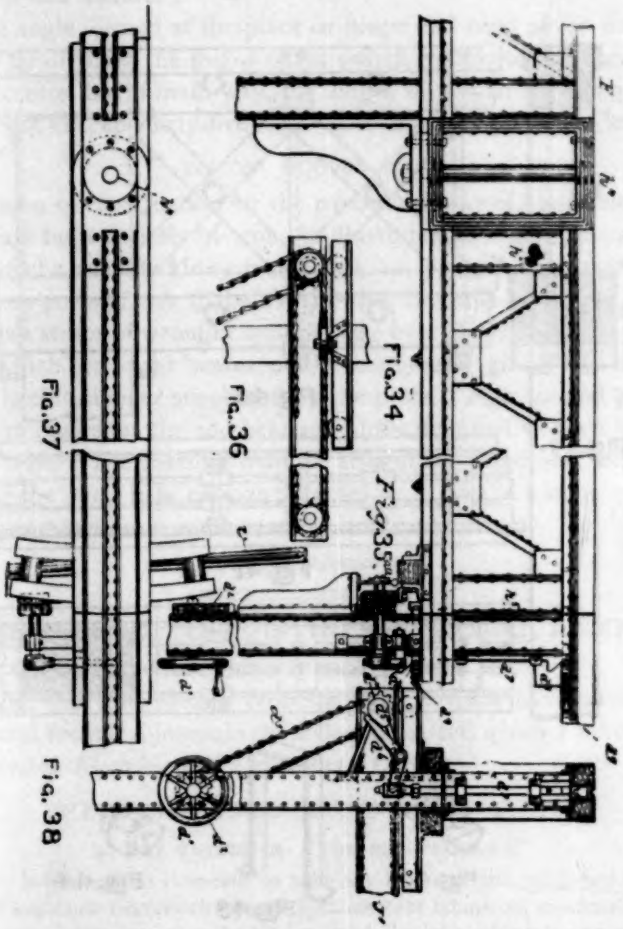
The switch, *Figs. 37* and *38*, consists in simply swinging a single section of the way upon a peculiarly constructed and very strong hinge attached to one of the posts.

In *Figs. 34* and *37*, *F*, and the continuance beyond the other post, d^9, are portions of the main line; h^5 h^5, the section composing the switch; h^4, its hinge, the whole being shown in plan in *Fig. 37*.

The movement of the switch must be sufficient to enable the cars and trucks on one track to clear the end of the rail on the

* Estimate of H. Haupt, C. E. In a timber country and with the cheapest possible wooden construction throughout.

other track, or some four or five feet. When operated, the free end is swung over upon the supporting carriage provided with rollers travelling upon the supporting rail *v*, being operated by suitable chains and rag wheels by means of a winch or hand-wheel,



d^1, *Fig. 38*, and locked in position by a locking device shown in *Figs. 35* and *38*. *Fig. 36* shows the connection of the rag-chain with the free end of the switch and its carriage.

The hinge is strongly bracketed out from the post at the end of the main way, *F*, as shown in *Fig. 34*, and consists of a series

of curved iron plates arranged concentrically around the pivot-pin or pintle, h^4. One-half of these plates are attached to the swinging section and one-half to the post, the series on each being composed of alternate layers of concave and convex ended plates which shut into each other so as to retain the strength of the track at this point

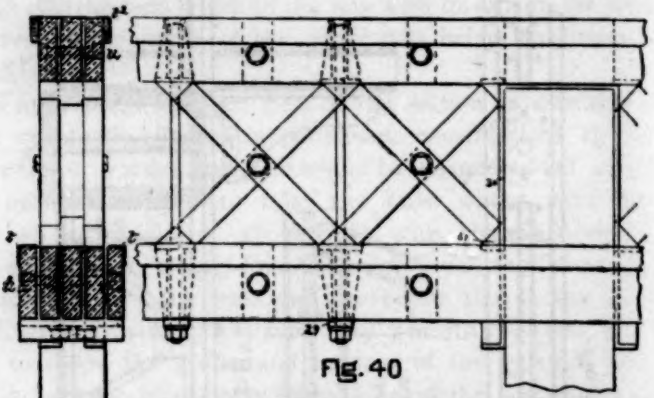


Fig. 40

Fig. 39.

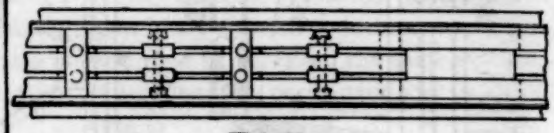


Fig. 41

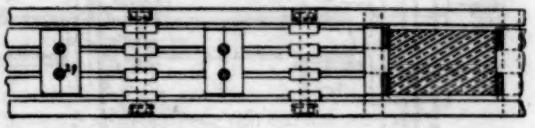


Fig. 42.

Fig. 43

Fig. 44

and yet form a hinge. In operating the switch, the first movement of the hand-wheel withdraws the locking spring-latch, d^9, from engagement with the girder, by means of the wedge-cam, d^8, and this device is also designed to be operated automatically by a moving train.

A singular effect of the inclined position or re-entrant angle of the truck wheels, described later on, has been found to be such that in running upon a switch left open even to the extent of fifteen inches, the switch will be closed by the train, thus increasing the safety of this feature.

The angle formed at the pivot or hinge end need never exceed 5°, for by dividing the throw of the switch equally to right and left of the centre line of main way, the length of switch truss required would not exceed thirty-five feet, which is a very moderate length.

IV. THE WOODEN WAY.

A form of construction for the permanent way of much less cost than that built entirely of iron, is illustrated in *Figs. 39–44*. It consists of a wooden Howe truss, *Figs. 39*, *40* and *41*, which may be set on posts of any shape, *t t*, showing the rails as before. *Fig. 43* shows straps of wrought iron passing over the tops of the posts, upon which the lower beams of the compound girder are hung, being in this manner supported by the posts. *Figs. 42* and *44* are cast-iron chairs for the end bearings of the diagonal wooden braces of the truss. The trussing may be altogether dispensed with by placing the posts near enough together, as it may be a more economical construction in some cases to adopt.

(*To be continued.*)

THE RECENT TESTS OF INCANDESCENT LAMPS.

TO THE COMMITTEE ON PUBLICATIONS:

Under this title, Messrs Woodhouse & Rawson have published in several technical journals the following letter, which I take from the London *Electrician* of December 11, 1885:

THE RECENT INCANDESCENT LAMP TESTS.

TO THE EDITOR OF "THE ELECTRICIAN:"

SIR: It was not our intention to take any notice of the published results of the FRANKLIN INSTITUTE tests on incandescent lamps, as, considering the very strong comments that had been made on the subject in the various electrical papers, we thought it most unlikely that any one would be misled by them. We have, however, been advised that unscrupulous persons—more especially on the Continent—have been taking advantage of these tests to disparage our lamps. We shall therefore be glad, if you will allow us the opportunity of emphatically denying that any reliance is to be placed in them, and of placing the following facts before your readers.

We were advised by our agent in America to have nothing to do with the tests, as they would not be reliable, the Swan, Maxim, and other makers of incandescent lamps having refused to allow their lamps to be entered. We, therefore, decided not to compete. Lamps, however, stated to be ours, were entered without our knowledge or consent, half being actually supplied by the Edison Company, the chief competitors, and the rest being obtained from another electric lighting firm. Whilst being admittedly run at five volts above what they were labelled, giving out up to forty per cent. or fifty per cent. above the proper candle-power, they were placed in competition with lamps evidently most carefully made and tested beforehand.

As an example of the way in which the electrical press have treated the tests, we may call attention to the *Electrical Review* of America, dated June 13th, in which are given verbatim reports of interviews with the President and Secretary of the INSTITUTE, the latter stating that he refused to have anything to do with the incandescent lamp tests, because he did not believe in them. Another official of the INSTITUTE stated some three months ago that it was very doubtful if the tests could be seen by outsiders, as the tests themselves did not agree.

Whilst in many instances disagreeing with the methods adopted in the actual tests, we refrain from criticising them, as we are well aware of the many difficulties that have to be contended with. We merely add that we think that the INSTITUTE ought to have seen that we were properly protected and advised of what was going on.

We are glad to hear that there is some chance of complete tests being made in this country, when every precaution will be taken to ensure their being properly made. Yours, etc., WOODHOUSE & RAWSON.

In this letter, Messrs. Woodhouse & Rawson repeat a calumnious statement of a New York paper of June 13, 1885, but omit to add the contradiction by the Secretary of the FRANKLIN INSTITUTE, published in the following number of that paper, of June 20th, as follows:

[*From the Electrical Review, June 20, 1885.*]

ED. ELECTRICAL REVIEW:

My Dear Sir:—Do me the favor to correct in your next, what I take to be an unintentional mis-statement of my remarks regarding the "Electrical Tests," which appeared in last week's issue, and for which I must disclaim responsibility.

I stated to your representative, as I have invariably stated to numerous other inquirers, that I could give little or no information regarding them, and that the proper person to apply to for information was Mr. Tatham. Beyond this, I do not recognize the statements credited to me as my own.

Yours truly,

WILLIAM H. WAHL,
Sec'y Franklin Institute.

Philadelphia, June 16, 1885.

No other notice, as far as I know, was taken of the article, and the story died of its own absurdity.

The reason given by Messrs. W. & R. for reviving this defunct slander is, that rival makers of incandescent lamps are prodding them with the report of the judges appointed by the FRANKLIN INSTITUTE to test the efficiency and duration of incandescent lamps.

It is true that the Swan, the Maxim and other companies did not enter their lamps for the tests, for various reasons, but no one had any right or reason to apprehend that they would not be fair tests, and no one now has any reason to say they were not conducted fairly.

In the conduct of the tests, the cardinal principle was to do right, and also to avoid all appearance of wrong-doing.

To this end, a code was adopted and judges selected, with the full concurrence of the contestants, and nothing was concealed from the parties in interest. The contestants were invited to inspect and did inspect every step in the progress of the tests. Their experts compared the photometric measuring powers of the judges with their own.

I believe it would be impossible to find four men better equipped and experienced for their duties morally, mentally and physically, than the four judges of these tests.

I was a daily witness of their work, and weekly progress reports of the tests were made to the FRANKLIN INSTITUTE.

So much for the general indictment; and now for the particular complaint.

It is, *first*, that their lamps were tested without their knowledge or consent. *Second*, that their lamps were run at five volts above what they were labelled.

Two lots of their lamps were tested. The first lot, selected at random from a barrel of lamps belonging to the Van Depoele Company, were labelled 20 candles, 55 volts. They were tested and run at fifty-five volts. No. 9, with resistance cold of 106 ohms, lived longest, 715½ hours. No. 2, resistance cold, 102 ohms, exhibited phenomenal brilliancy.

The complaint that this lot of lamps was entered without their knowledge or consent, may be well founded.

The second lot of lamps was received through the Edison Com-

pany. I now learn that the origin of this transaction was as follows:

At a meeting of the London Society of Arts, held December 3, 1884, Mr. Wm. H. Preece, F. R. S., read a paper upon "Electric Illumination," in which appeared the following language [see *Journal of the Society of Arts*, December 5, 1884, page 73]:

"The efficiency of the glow lamps has also been very considerably affected by the improvement made, for instance, by Messrs. Woodhouse & Rawson and by Mr. Bernstein.

"The efficiency of the Edison lamps means the consumption of energy at the rate of five watts per candle, but lamps are now being made which give an efficiency of two and a-half watts per candle with an equal life, which is equivalent to an immediate reduction of fifty per cent. in the amount of energy required to maintain the system alight, and therefore in the cost of production."

Whereupon, the Edison Company challenged Mr. Preece to produce such lamps and have them tested by the FRANKLIN INSTITUTE, whose committee was preparing for the tests which afterwards were made.

Mr. Preece procured the lamps and forwarded them to the Edison Company, whose letter dated April 13, 1885, to Professor Marks (who acted as an executive committee), says: "Mr. Preece, the electrician of the English Post Office, has sent to Mr. Edison a number of Woodhouse & Rawson lamps. They are now in the New York Custom House. We have given directions to have them forwarded to you at the Electrical Exhibition in the original packing as soon as they are appraised."

At that time our test boxes were all occupied and our current employed.

Inside of the box when received, was found a large label addressed "for Mr. Wm. H. Preece, 20 candles, 50 volts." The usual label of Woodhouse & Rawson was on every lamp, altered however, so as to read as above, the figure 0 in the number 50 being written over an erasure. The resistances, cold, of all the lamps tested was nearly uniform, five at 100 ohms; two, each ninety-nine and 101 ohms, and one 102 ohms. [See Report, Table VI, page 38.]

These circumstances persuaded us that the lamps were not selected by chance.

They were tested and measured for horizontal and spherical efficiency upon the 7th May, both at fifty volts and at fifty-five volts with the results shown in the following table, which I have made up from the original records.

WOODHOUSE & RAWSON LAMPS. (Second lot.)

Measurements of Horizontal and Spherical Efficiency, at 50 Volts and at 55 Volts, Compared. Made May 7, 1885.

Lamp No.	Volts.	Ampères.	Watts.	CANDLES AVERAGED.		Watts per Spherical Candle.	Watts per Horizontal Candle.
				Horizontal.	Spherical.		
30	50·	1·071	53·75	14·19	11·48	4·68	3·79
	55·	1·167	64·18	22·73	18·52	3·46	2·82
31	50·	1·084	54·20	12·38	9·93	5·46	4·38
	55·05	1·182	65·07	20·93	17·28	3·76	3·11
32	50·03	1·084	54·23	12·43	10·47	5·18	4·36
	55·	1·195	65·72	21·28	17·36	3·78	3·09
33	50·	1·089	54·45	14·07	11·75	4·63	3·87
	55·05	1·188	65·40	22·67	19·01	3·44	2·88
34	50·03	1·050	52·53	12·52	10·34	5·08	4·20
	55·	1·147	63·08	20·78	16·91	3·73	3·04
35	49·95	1·046	52·25	14·48	11·73	4·45	3·61
	54·95	1·139	62·58	23·53	19·56	3·20	2·66
36	49·95	1·088	54·35	15·68	13·05	4·16	3·47
	55·	1·191	65·50	25·98	21·41	3·05	2·52
37	50·	1·086	54·33	13·88	11·51	4·72	3·91
	55·	1·185	65·17	22·93	18·74	3·47	2·84
38	50·05	1·097	54·90	12·24	10·05	5·46	4·49
	55·	1·197	65·77	20·70	17·84	3·69	3·18
39	50·	1·089	54·45	11·88	9·73	5·59	4·58
	55·	1·186	65·23	19·74	16·33	3·99	3·41
Average	50·	1·0784	53·944	13·375	11·004	4·941	4·066
Average	55·	1·1777	64·770	22·127	18·296	3·557	2·955

Upon discussing these preliminary results, the judges found it impossible to follow the label. Twenty candles illumination could not be had with fifty volts, and they decided to raise the electro-motive force for the following reasons: There are three points of excel-

lence in incandescent lamps—brilliancy, duration and economy. The boast for these lamps is that they are brilliant and cheap. It would not benefit their reputation to test them with fifty volts, at which the preliminary tests show that they are both dim and dear, for the sake of increasing their duration, of which the remaining time of the tests, about 300 hours, would furnish no proof.

In this decision the judges were governed by a desire to do for the lamps what they thought the makers would do if they had been present and aware of all the facts. The judges made no concealments of what they did, nor of their reasons for it. They published the results of the tests with fifty volts, but not prominently.

It was out of kind consideration for the makers of the lamps that the judges raised the electro-motive force, and it was out of a like consideration that they did not publish a table like the above.

These considerations, Messrs. Woodhouse & Rawson have trampled under their feet and have turned again to rend the committee.

I am unable to see the least shadow of unfairness in the proceedings of the judges, and I ask all those journals which have published the letter of Messrs. Woodhouse & Rawson to publish this reply.

I am, very respectfully,

W. P. TATHAM,

President of the FRANKLIN INSTITUTE.

ACTION OF LIGHT ON CHLOROPHYLL.—C. Timiriazeff experimented upon chlorophyll by Draper's method of decomposing portions of the previously dispersed light. His results show that chlorophyll acts as a true sensitizer, undergoing decomposition itself, and promoting the decomposition of carbonic anhydride in those parts of the spectrum which it absorbs. The different rays absorbed by chlorophyll produce decomposition in very different degrees, the maximum decomposition coinciding in a remarkable manner with the maximum energy in the normal spectrum as measured by Langley and Abney. It would seem, therefore, that it is the amplitude rather than the period of the vibrations which brings about that disturbance of the carbonic anhydride molecule which finally results in its dissociation. The chemical action of light on the photographic plate seems to be strictly analogous to its physiological action on the living plant, provided that, as in the case of chlorophyll, the absorption phenomena are identical in both cases.—*Jour. Chem. Soc., July, 1885.*

BOOK NOTICES.

THE WINDMILL AS A PRIME MOVER. By Alfred R. Wolff, M. E. New York: John Wiley & Sons, 1885.

Windmills are applicable only where a continuous power is not needed, or where it is possible to store up power for future use, but in these cases they are undoubtedly the most economical of prime movers. A complete treatise on this subject is therefore a welcome addition to mechanical literature.

In the above-mentioned treatise, the subject is well represented, both in its theoretical and practical bearings.

After a careful analysis of the dynamical effect of air projected upon flat surfaces, the theoretical results of the investigation are compared with those of other writers as well as with the results of actual tests.

A digest of the historical development of the windmill is followed by the detailed description of the principal modern constructions as made and used in this and other countries.

The comparisons of economy with other prime movers form a very interesting addendum, in showing the advantages, in this respect, of windmills.

H. B.

A TEXT-BOOK ON THE MECHANICS OF MATERIALS, AND OF BEAMS, COLUMNS AND SHAFTS. By Mansfield Merriman, Professor of Civil Engineering at Lehigh University. New York: John Wiley & Sons, 1885.

It is not here attempted to bring forward new facts or formulæ, but simply to give a clear and scholarly presentation of those already in use, with so much of explanation as the dignity of the young collegian can be expected to take without resentment; and this the author has admirably done. The book is precisely what its title indicates. It gives concisely, but fully, the laws governing the behavior of materials under stress, with brief statements of the average strengths, etc., of the substances in most general use, and is not cumbered with lengthy statistical tables, which, in such a book, would be out of place. It is written for young men at school, who have their mechanics at their fingers' ends, and the professor very properly draws upon their stock with considerable freedom. Still, the greater part of the work is available, and must prove very useful, to those practitioners who are not satisfied with merely having things right, but who who wish to refresh their recollection as to the "reason why."

The book is in good, clear type, and well printed, except the cuts, many of which are coarse and indistinctly lettered. There are but some sixteen fundamental formulæ, and the finding of these would be greatly facilitated by stating their *pages* in the references to them.

T.

THE ANEMOGEN.—Bishop Rougerie gives this name for an apparatus which produces air currents imitating the principal winds. It is composed of a small artificial terrestrial globe, rotating in the air and producing currents analogous to the trade winds, the equatorial calms, the variable winds, the reversal of the trade winds by the Southwest monsoon, as well as the ascending and descending currents at the poles, the equator and the regions of maximum barometric pressure.—*Comptes Rendus, Sept. 7, 1885.*

Franklin Institute.

[*Proceedings of the Annual Meeting, held Wednesday, January 20, 1886.*]

HALL OF THE INSTITUTE, January 20, 1886.

MR. WM. P. TATHAM, President, in the Chair.

Present—206 members and fourteen visitors.

Nineteen new members were reported as having been elected at the last meeting of the Board of Managers.

The President presented the Annual Report of the Board of Managers, approved at the Stated Meeting, held Wednesday, January 13, 1886:

ANNUAL REPORT OF THE BOARD OF MANAGERS FOR THE YEAR 1885.

The Board of Managers of the FRANKLIN INSTITUTE of the State of Pennsylvania for the Promotion of the Mechanic Arts, respectfully present the following report of the operations of the INSTITUTE for the year 1885:

MEMBERS.

Number of new Members elected who have paid their dues,		198
Lost by death and resignation,	29	
Dropped for non-payment of dues,	45	
	—	74
		124
Total Membership at close of 1885,		2,257

FINANCIAL STATEMENT.

Receipts.

Balance on hand, January 1, 1885,		$6,929 80
Exhibition of 1884,	$3,575 10	
Exhibition of 1885,	42,000 00	
Temporary loan,	23,000 00	
New tests (returned)	50 07	
Editing Committee (Publication of Reports of Electrical Exhibition),	144 68	
Memorial library contributions,	650 00	
Other receipts,	13,573 08	
		82,992 93
		$89,922 73

Payments.

Exhibition, 1884,	$2,987 61		
Apparatus,	1,418 35		
		$4,405 96	
Exhibition of 1885,	$49,288 63		
Insurances,	1,836 50		
		51,125 13	
Competitive tests (electrical),		5,422 87	
Editing Committee of Electrical Exhibition, publication of reports,		1,836 50	
Temporary loan,	$8,000 00		
Interest,	177 45		
		8,177 45	
Cash in hands of Actuary,		420 00	
Other expenditures,		17,724 04	
			$89,111 95
Balance on hand December 31, 1885,			$810 78

It appears from the above statement that the INSTITUTE still owes $15,000 temporary loan, as against the value of the Exhibition property.

LIBRARY.

During the year 1885, the Library has continued to grow in the number of books and to improve as to their condition. The report of the Library Committee will show an addition of 6,280 books and pamphlets during the year. For the first time, the large collection of pamphlets belonging to the INSTITUTE has been classified and indexed, so as to be accessible to readers. This work is not yet finished. The continued effort to complete valuable serials has been successfully exerted. The increase to the Library has compelled the Committee to build up many of the cases to the ceiling and to stow out of sight, or remove to the upper floors of the building, many books which are seldom consulted. If we have no relief in the way of increased accommodation, it will soon be useless to make efforts to increase the number of books.

JOURNAL.

The JOURNAL has continued its usefulness. It has been very much enriched during the past year by the supplements added to each number, containing many valuable reports of the Electrical Exhibition, which will be referred to for many years to come. The general index remains unfinished.

LECTURES.

The following lectures were officially approved and delivered during the year 1885:

By Dr. N. A. Randolph, *two* lectures, on "The Chemistry of Nutrition;" Mr. C. J. Hexamer, *two*, on "Means for Extinguishing Fire," and on "Spontaneous Combustion;" Prof. E. J. Houston, *three*, on "Earthquakes and Volcanoes;" Prof. E. D. Cope, *one*, on "The Evolution of the Vertebrata;" Dr. Wm. H. Wahl, *one*, on "Electro-Metallurgy;" *one* by Prof. Thos. M. Drown, on "The Metallurgy of Iron;" *one* by Mr. Pedro G. Salom, on "The Metallurgy of Steel;" *one* by Prof. Geo. A. Koenig, on "The Metallurgy of Copper;" *one* by Dr. Henry F. Formad, on "The Present Status of the Germ Theory of Disease;" *five* by Mr. R. D. Baker, on "Elementary Chemistry;" *one* by Prof. Coleman Sellers, on "Scientific Method in the Workshop;" *one* by Lieut. Bradley A. Fiske, U. S. N., on "Electricity in Warfare;" *one* by Mr. Coleman Sellers, Jr., on "Oliver Evans and his Inventions;" *one* by Lieut. John P. Finley, U. S. Signal Corps, on "Tornado Study," etc.; *one* by Mr. A. H. Emery, on "Testing Machines as Instruments of Precision;" *three* by Dr. N. A. Randolph, on "Food, Nutrition and Digestion;" *one* by Wilfred Lewis, on "The Mechanical Powers," and *one* by Dr. Wm. H. Wahl, on "Water Gas."

The above list comprises twenty-eight lectures, most of which were illustrated. They were, as a rule, well attended, and a number of them have been deemed of sufficient importance to warrant their publication in the JOURNAL.

The plan of issuing *free* tickets, to members and others, admitting five minutes before 8 o'clock, was continued.

COMMITTEE ON SCIENCE AND THE ARTS.

This Committee, during the year 1885, reported upon thirty-two applications, in three of which they recommended the award of the Elliott Cresson medal; in ten, the award of the John Scott Legacy Premium and Medal (all of which were approved, respectively, by the INSTITUTE and by the Board of City Trusts); and in one case, a Certificate of Merit. Twenty-two applications are still pending before the Committee.

EXHIBITION.

The Exhibition of 1885 opened upon the 15th of September and continued until the end of October. Although it contained many exhibits of great value and originality, which ought to have been appreciated, it must be confessed that the attendance of visitors was less than had been hoped for. The valuable investments made for the purposes of this exhibition remain the property of the INSTITUTE, and will reduce the cost of holding another, if it should be determined to do so.

DRAWING SCHOOL.

The Board report the condition of the Drawing School as satisfactory.

The attendance at the Spring term, 1885, was	143
" " " Fall " "	190
Whole number, ...	333

The pupils, on finishing their course of instruction, are generally competent to engage as draughtsmen.

SECTIONS.

The Chemical and Electrical Sections of the INSTITUTE have displayed great activity, and their annual reports to be presented to the INSTITUTE, show large increase of membership and usefulness.

Respectfully submitted,

W. P. TATHAM, *President.*

Annual Reports of the Chemical, Electrical and Phonetic Sections, and of the Committee on Library, were read, accepted and referred for publication.*

The annual election, held this day, resulted in the choice of the following officers:

For President, (to serve one year,) CHAS. H. BANES; for Vice-President, (to serve three years,) FREDERICK GRAFF; for Secretary, (to serve one year,) WILLIAM H. WAHL; for Treasurer, (to serve one year,) SAMUEL SARTAIN; for Auditor, (to serve three years,) WILLIAM A. CHEYNEY; for Managers, (to serve three years,) GEORGE V. CRESSON, PERSIFOR FRAZER, WILLIAM HELME, EDWIN J. HOUSTON, ENOCH LEWIS, WILLIAM P. TATHAM, WILLIAM H. THORNE, JOHN J. WEAVER.

Mr. EUGENE H. COWLES read the paper of the evening, on "The Production of Aluminum and its Alloys in the Electric Furnace." (The paper and discussion thereon, appear in this impression of the JOURNAL.)

WILLIAM H. WAHL, *Secretary.*

VALUE OF THE OHM.—Mascart, De Nerville and Benoit have experimented, in accordance with the programme of the International Commission, in order to determine the dimensions of the mercury column at 0°, which represents the unit of electric resistance. The absolute resistance of a conducting circuit was measured by the quantity of induced electricity, which traversed it when it was displaced in the terrestrial magnetic field (Weber's first method), or when it was submitted to the action of a neighboring current (Kirchoff's method). The two methods employ the same instruments and have many common characteristics, which furnish the elements for a reciprocal check. The results by Kirchhoff's method agree the most closely and give the value for the ohm of 106·30 cm. The experiments by Weber's method, on the coil which was most carefully studied, give precisely the same value. The paper closes with the results obtained by different experimenters, the averages of the several methods being as follows: Permanent deviation of a magnet by a turning frame, 105·82; discharge induced in a frame for a rotation of 180°, 106·15; discharge induced by a current, 106·08; continuous induction current, 106·13; deadening magnets, 105·60; heat disengaged by a current, 106·22. Glazebrook, in 1882, obtained the value 106·29; Rowland and Kimball, in 1884, 106·31; Rowland, Kimball and Duncan, in 1884, 106·29.—*Ann. de Chim. et de Phys, Sept., 1885.*

* These reports will appear in the March number of the JOURNAL.